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Editor's Page

Champions of transformation

While new and exciting technologies become available to us at a rapid pace, realizing their benefits takes people with the willingness to try new approaches, and the insight to put them into practice. Last month, at the Connected Plant Conference (www.connectedplantconference.com), 15 individuals and teams were recognized for their roles in taking the lead to make progress in the chemical process and energy industries through their implementation of IIOT-(industrial internet of things) related technologies. The following were honored as "Game Changers" at the conference:

Manuel Lombardero, AES — Manuel digitalized the lubrication maintenance program at his company, making information, such as specifications, procedures and more, accessible to mobile devices.

Albert Rooyakkers, Bedrock Automation — Albert produced an open and secure platform for industrial control systems, and started a company where cybersecurity is intrinsic to its control offerings.

Kim Gilbert, Beyond Limits — Kim is leading a team to develop architecture for the world's first cognitive power plant, which will be installed as part of a large-scale infrastructure program in West Africa.

SEIGA Team (Seamless EPCOM Integrated Global Access), Eastman Chemical Co. — The team created an integrated digital EPCOM (engineering, procurement, construction, operations and maintenance) environment to automate engineering workflows and more.

Juan Panama, Emerson — Juan has helped numerous end users solve challenges through innovative sensing technologies, software and more.

John Chowdhury, Frisco Green Energy — John's leadership was instrumental in connecting all hydro, gas and solar power under one management system at Southern California Edison (SCE).

Michael Parrella and Martin Shimko, GTherm, Inc. — Michael and Martin invented a Comprehensive Enhanced Oil Recovery System, for which GTherm Energy, Inc. was recently awarded a patent.

Jared Witte, Kuraray America — The Champion award winner, Jared moved his organization from one that relied on historical trends and laboratory results to real-time process data, enabling data-driven decisions.

Todd Synoground, Ashley Ward, Amy Basche and Jeff Flora, Mission Support Alliance — This team utilizes HoloLens, which provides a mixed-reality platform to enhance operational efficiency, improve maintenance planning, modernize training and more.

Samer Arafa, Justin Woodard and Tyler Krupa, National Grid — They developed advanced photovoltaic facilities to better understand the impact that advanced technologies can have on the energy grid.

Carlos Sua and Annamalai Lakshmanan, NextEra Energy Resources — A remote-service guidance program, using smart glasses, was developed to help wind-power technicians get expert advice remotely.

Jay Panicker and Prabhakar Nellore, OpenEGrid — This team created open-standards-based communications systems to enable joint control of the emerging "Smart Grid."

Smart Wires Team — Smart Wires developed a modular technology that allows utilities to dynamically control the power flows on their network.

Andy Tang, Wärtsilä — Andy and his team have connected customers with GEMS, a platform that enables them to tap into the full potential of renewables and eliminates intermittency issues.

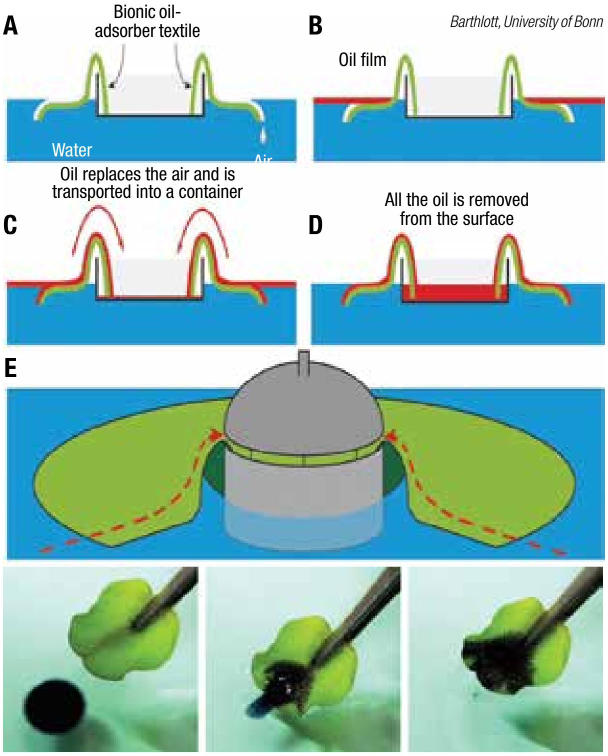
Benjamin Blanchette, Georgia-Pacific — Ben champions long-term advantages by quickly recognizing and adopting new technologies. ■

Dorothy Lozowski, Editorial Director

Bio-inspired textiles recover oil from water

A technology that removes oil from the surface of water without pumps or chemicals has been developed by German researchers at the Universities of Bonn (www.uni-bonn.de) and Aachen (www.uni-aachen.de) and textile-manufacturer Heimbach GmbH (Düren, Germany; www.heimbach.com). Textiles with special surface properties passively skim off the oil and move it into a floating container. The study has now been published in the journal *Philosophical Transactions A*.

The textile surfaces are modeled after the floating fern *Salvinia*: its leaves are superhydrophobic, so when submerged they wrap themselves in an air jacket and remain completely dry. At the same time, the *Salvinia* surface is superoleophilic. "This allows the leaves to transport an oil film on their surface [photos]," explains Wilhelm Barthlott, professor emeritus of the University of Bonn and former director of its botanic gardens. "And we have also been able to transfer this property to technically producible surfaces, such as textiles."



Unlike other materials that have been used for soaking up oil spills, these "bionic oil adsorbers" (BOAs) do not absorb the oil. "Instead, it travels along the surface of the fabric, moved forward solely by its adhesive forces," explains Barthlott.

The BOA device consists of a buoyant container with the oil-adsorbing textile attached at the edge (diagram). The submerged portion initially holds an air film. The air becomes displaced by the oil as it is adsorbed and is transported to the storage container. This transport only stops when the oil level inside the container has the same height as the water surface/oil film level outside of the container (or when all the oil is adsorbed).

The procedure is not intended for large-scale oil disasters, such as those that occur after a tanker accident. But particularly small contaminations, such as engine oil from cars or ships, heating oil or leaks, are a pressing problem. "Even minor quantities become a danger to the ecosystem, especially in stagnant or slow-flowing waters," emphasizes Barthlott. This is where he sees the major application potential of the new method, for which a patent has been filed by the University of Bonn.

Converting solid waste to ketones

Researchers at Lawrence Berkeley National Laboratory (Berkeley, Calif.; www.lbl.gov) recently reported a process for converting various blends of cellulosic biomass and municipal solid waste (MSW) into aliphatic methyl ketones. The team used bio-derived ionic liquids to first break down the solid waste materials in a pretreatment step. Then, they followed that with a fermentation step in which genetically engineered *Escherichia coli* convert sugars resulting from the bio-ionic-liquid processing into ketones, which can be used as diesel fuel precursors and for fragrances and flavors.

The process yielded up to 1,145 mg/L of methyl ketones in the C11 to C17 range from biomass-MSW blends, the researchers say. "The ionic liquid-based conversion represents an efficient and more environmentally friendly process for biomass upgrading," says Berkeley Lab researcher Ning Sun, the study's lead author. "This opens the door to building biorefinery facilities that use diversified feedstocks to produce a range of chemicals." The Berkeley Lab team created six blends that combined MSW items (non-recyclable paper and grass clippings) with biomass (corn stover and switchgrass), and scaled up one of these blends 30-fold. They are currently attempting to scale up the process even further, Berkeley Lab says.

Edited by:
Gerald Ondrey

CAPROLACTAM

Genomatica (San Diego, Calif.; www.genomatica.com) recently announced the production of the world's first renewably sourced ton of caprolactam, the key ingredient for nylon-6. The company made the caprolactam by fermenting plant sugars with engineered microbes, departing from the conventional route for nylon-6, which uses crude oil as a feedstock.

Genomatica's bio-based caprolactam will be used to produce 100% renewably sourced nylon that delivers equivalent performance to conventional nylon, but with lower environmental impact. Traditional nylon production from crude oil is responsible for an estimated 60 million ton/yr of greenhouse gas emissions, Genomatica says. The bio-based caprolactam is converted into nylon-6 polymer chips and yarn by Aquafil (Arco, Italy; www.aquafil.com), a major European nylon producer and Genomatica partner, in Slovenia.

INCREASING PEM LIFE

Membrane degradation in fuel cells is cut in half thanks to a new electrode catalyst developed by the New Energy and Industrial Technology Development Organization (NEDO; Kawasaki City, Japan; www.nedo.go.jp) in collaboration with Yamanashi University and Tanaka Kikinzoku Kogyo K. K. (Tokyo, www.tanaka.co.jp). The Pt–Co alloy hydrogen electrode works by suppressing the generation of H_2O_2. Hydroxyl radicals (·OH) are responsible for much of the degradation of the proton-exchange membranes (PEMs) used in fuel cells. The conventional approach has been to use radical scavengers incorporated into the PEM, but this decreases the performance.

Now, the research team has

(Continues on p. 6)

taken a counter-intuitive strategy in which the production of H_2O_2 — the precursor of ·OH radicals — is suppressed at the hydrogen anode, where oxygen diffusing from the cathode is reduced by adsorbed hydrogen atoms. This is accomplished via the use of a Pt-skin-covered PtCo alloy anode catalyst. A remarkably longer lifetime of a PEM with the PtCo/C anode, in comparison with that for a commercial Pt/C anode, has been demonstrated in an accelerated stress test of a single cell.

POROUS MOFS

A new porous material that generates H_2 when irradiated with light has been developed by a Japanese collaboration between Kwansei Gakuin University (global.kwansei.ac.jp), Japan Synchrotron Radiation Research Institute (JASRI; Hyogo Prefecture, www.jasri.jp) and Japan Science and Technology Agency (JST; Tokyo; www.jst.go.jp). Recently, metal-organic frameworks (MOFs) composed of sulfur secondary building units (sulfur-SBUs) have attracted significant attention as electronic materials with unique properties, such as high conductivities and photo- and electrocatalytic behavior. The researchers reported the crystal structure of KGF-1, an example of a Pb-MOF composed of three-dimensionally

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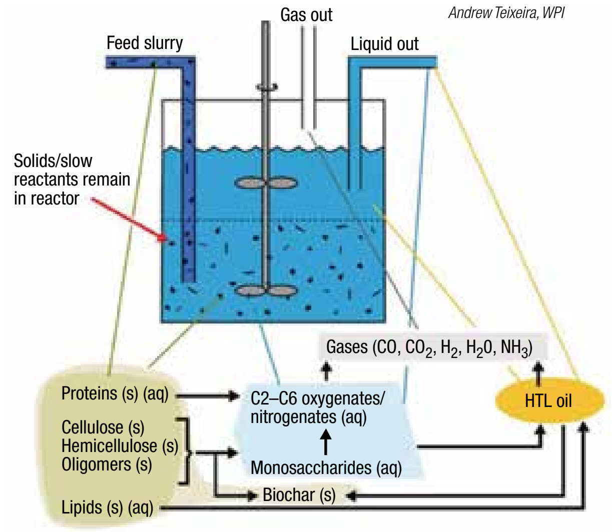
Simultaneously treat many mixed-waste streams



A team of researchers at Worcester Polytechnic Institute (WPI; Worcester, Mass.; www.wpi.edu) are investigating hydrothermal liquefaction (HTL) to simultaneously treat a variety of municipal waste streams and create biofuels. "HTL is an emerging technology for the conversion of various types of aqueous streams containing organic components, including biomass, food, sewage sludge and many others," explains WPI chemical engineering professor Michael Timko. In HTL, the feedstream is heated while system pressure is maintained at a level sufficient to maintain water in its liquid state. At these conditions, depolymerization, dehydration and hydrolysis reactions occur, yielding an energy-dense oil that can be upgraded as diesel blendstock, along with a carbon-rich solid char, a CO_2-rich gas and an aqueous phase. A major benefit of HTL is speed — its reactions take just minutes, whereas conversion via anaerobic digestion, the incumbent technology, can require multiple days. Hydrothermal liquefaction also avoids other challenging aspects of anaerobic digestion, including incomplete digestion of lignin and crystalline cellulose, microbial susceptibility to toxins and the production of byproducts that necessitate additional purification. Since the technology handles aqueous streams, no drying is required, which further improves process economics.

Timko's team is looking at a variety of catalytic platforms for their HTL process, including bauxite tailings, also known as "red mud," an abundantly available waste product of alumina processing. "Red mud has diverse acid and base sites that are appropriate for promoting depolymerization and recombination reactions that help funnel carbon through desirable oil-producing pathways and away from byproducts," says Timko. The team has tested the process with different combinations of yard and food waste to produce oils. "In principle, any aqueous stream with greater than about 10 wt. % organic content is worth investigating. Plastics upcycling is an emerging area we are currently exploring," adds Timko. The project currently uses 100-g reactors, but plans are in place to expand to kilogram-scale and also evaluate continuous processing. Timko notes that an important consideration with HTL scaleup is to balance the economies of scale for larger-scale facilities versus maintaining modular reactors, which benefit from reduced feed-transportation costs.

Validating hydrogen-embrittlement models for steel tanks

Hydrogen is transported in steel tanks and pipelines. However, H_2 causes embrittlement of steels by accumulating at microstructures called dislocations and at the boundaries between the individual crystals of which the steel is composed. The accumulation of hydrogen weakens the steel along those features, leading to embrittlement that could allow the steel to fracture easily. Measuring the precise location of hydrogen atoms in steel has been challenging. Previous methods, such as thermal desorption spectroscopy, could identify hydrogen trapping, but could not easily identify the relative contributions of different microstructures.

Now, an important improvement in the safe production, storage and transportation of hydrogen has been found by a team from the University of Sydney (Sydney, Australia; sydney.edu.au), CITIC Metal Co. (Beijing, China), University of Science and Technology Beijing (China), Microscopy Solutions Pty (Caulfield North, Australia), and Shanghai Jiao Tong Univesity (Shanghai, China), led by Sydney University professor Julie Cairney. The team used cryo-transfer atom probe tomography to observe hydrogen at specific microstructures in steels. Direct observation of hydrogen at carbon-rich dislocations and grain boundaries provides validation of embrittlement models.

The team also found that clusters of niobium carbide within the steel trap hydrogen so that it cannot easily move to the dislocations and crystal boundaries to cause embrittlement. Hydrogen observed at an incoherent interface between niobium carbides and the surrounding steel provides direct evidence that that these incoherent boundaries can act as trapping sites. This information is vital for designing steels that can resist embrittlement, says Cairney.

Centralized control system infrastructure

At the ARC Industry Forum in February, Honeywell Process Solutions (HPS; Houston; www.honeywellprocess.com) released the Experion PKS IT Highly Integrated Virtual Environment (HIVE), a new technology that centralizes up to 80% of IT infrastructure used in project engineering. The PKS IT HIVE untethers industrial enterprises from running IT workloads where their controllers are located — instead giving them the freedom and flexibility to run workloads on-site, at a remote data center, or a combination of both, says Joe Bastone, director of Experion PKS product management. This enables control systems to be engineered and implemented in less time, at lower cost and risk, and with simpler, modular builds. The new solution allows customers to view and manage their entire infrastructure through a single dashboard at any given location, via a network tunnel that uses existing wide-area networks (WANs), rather than dedicated new infrastructure.

Centralizing IT infrastructure and reducing networking and computing resources required to run on-site allows users to reduce maintenance and free process control engineers from administration to focus on higher-value activities, including process optimization, Honeywell says. Furthermore, centralization allows users to eliminate unused computing infrastructure and benefit from the latest virtualization technology.

The IT HIVE is one of three elements that form Experion PKS HIVE, an approach that seeks to unchain control applications from physical equipment, and controllers from physical input/outputs (IO). The other two are PKS IO HIVE, which provides flexible IO and control distribution, enabling the control system to become a natural extension of process equipment and to facilitate modular and parallel project execution; and PKS Control HIVE, which uniquely applies control containers to provide flexibility and standardization of control hardware platforms, control location and engineering.

extended sulfur-SBUs that displays molecular sieving behavior, visible-light absorption, and a semiconductor band structure, as well as being a hydrogen-evolution photocatalyst.

REDOX FLOW BATTERIES

BASF SE (Ludwigshafen, Germany; www.basf.com) and JenaBatteries GmbH (www.jenabatteries.com) are cooperating in the production of an electrolyte for a battery technology that is particularly suitable for stationary storage of electricity from renewable energy sources and for stabilizing conventional transmission grids. JenaBatteries, which has developed this technology based on a so-called redox flow battery (RFB) with organic materials, thus has the world's first commercially available technology of this kind. Two liquid organic electrolytes separated by a membrane and stored in separate tanks store the current. BASF will supply one of the two electrolytes

(Continues on p. 8)

as part of the collaboration. This battery material is based on an amine, a chemical intermediate that the company can produce on an industrial scale. JenaBatteries plans to market the first RFB in 2020. (For more on RFBs, see *Chem. Eng.*, September 2016, pp. 14–20).

'GREEN IT'

Goethe University (Frankfurt am Main, Germany; www.uni-frankfurt.de) and the GSI Helmholtz Centre for Heavy Ion Research (Darmstadt, both Germany; www.gsi.de) were recently granted a European patent for their concept for an energy-efficient cooling structure for data centers. This patent now paves the way for the commercialization of the pioneering technology developed by professor Volker Lindenstruth, professor Horst Stöcker and Alexander Hauser of e3 computing GmbH (Frankfurt; www.e3c.eu). Together with parallel patents outside Europe, the invention can now be put to economic use throughout the world. The team has already received inquiries from various countries for the construction of such data centers. NDC Data Centers GmbH (Munich; www.ndc-datacenters.com) has

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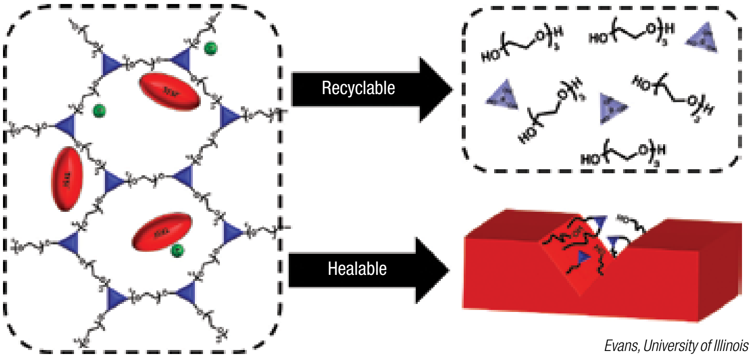
Self-healing, recyclable solid electrolytes for Li-ion batteries



Evans, University of Illinois

Energy-storage researchers have been in search of safer electrolytes for lithium-ion batteries, because of persistent concerns over possible overheating and fires resulting from dendrite formation in the anode. Solid polymer electrolytes have been explored to address these issues, but achieving the desired properties of safety and conductivity is challenging. Researchers at the University of Illinois at Urbana-Champaign (https://illinois.edu) have developed a new solid battery electrolyte material capable of self-healing behavior that could make Li-ion batteries safer by suppressing dendrite formation. The material has the added benefit of being easily recyclable.

The research team, led by Chris Evans, developed dynamic polymer networks capable of exchanging covalent crosslinks and examined the material's ability to conduct Li cations. The bond exchange allows the material to self-heal when damaged, a property that could help withstand the formation of dendrites and prevent safety hazards.

The solid electrolyte material consists of a poly (ethylene oxide) scaffold containing boronic ester crosslinks, and a lithium salt — lithium bis (trifluoromethanesulfonyl) imide; LiTFSI — as a source of Li cations (diagram). Evans says the choice of boronic esters allows the electrolyte material to dissolve in water, enabling it to be readily recycled.

While investigating the conductivities of the dynamic polymer network, the researchers found that they are not quite as high as those seen in liquid electrolytes, but Evans says the new materials perform as well as most other solvent-free polymer-based electrolytes.

The Illinois research group envisions the dynamic network technology as a platform, in which different chemistries could be employed for the dynamic bonds and different mechanical properties and conductivities could be possible. They are now focused on evaluating a broader range of bonds and operating conditions to determine the ultimate potential of the new electrolyte material, Evans says.

Commercializing vacuum-microwave drying for pharmaceuticals

Vacuum-microwave drying is much faster than other techniques, such as freeze drying or air drying, but the difficulty in achieving homogenous microwave-energy distribution under vacuum conditions has made it difficult to scale up for commercial manufacturing. "What tends to happen is a concentration of energy, and plasma discharge can readily occur, which can burn the product and damage equipment," explains Brent Charleton, president and chief executive officer of EnWave Corp. (Vancouver, B.C., Canada; www.enwave.net). EnWave has developed proprietary technology that minimizes the probability of plasma discharge at varying vacuum levels, providing an even, controllable drying process. The technology has already been deployed into the food sector, and EnWave has been working with Merck KGaA (Darmstadt, Germany; www.merck.com) to fine-tune a pilot unit designed for the biopharmaceuticals sector, which Charleton says is the first continuous vacuum-microwave machine that meets Good Manufacturing Practice (GMP) regulations.

"We can dry many vaccines simultaneously in a continuous fashion. The primary goal is to eliminate the cold-chain storage requirement for that product and still maintain efficacy," says Charleton. Now, EnWave has partnered with GEA Lyophil GmbH, part of GEA Group AG (Düsseldorf, Germany; www.gea.com), to evaluate scaleup and commercialization options on the basis of the Merck pilot unit. Right now, GEA and EnWave are working to ensure that large-scale units can meet the stringent traceability and repeatability requirements demanded for pharmaceutical products.

In vacuum-microwave dryers, product enters a vacuum chamber where an array of magnetrons elicits a predetermined amount of microwave energy based on maintaining a certain temperature profile to reach the desired decrease in moisture. Microwave energy is absorbed by organic materials on the first pass, and unabsorbed energy is either reflected off the stainless-steel vessel interior and back through the product load to maximize absorption, or absorbed by a water load to eliminate the propensity for plasma discharge to occur. Typically, says Charleton, 85–90% of energy is absorbed by the product load.

obtained the rights to market the green technology in data-center construction projects around the globe.

The basis for these activities is the visionary concept of a significantly optimized cooling system for data centers with the highest possible energy efficiency. This was developed by Lindenstruth, professor for High-Performance Computing Architecture at Goethe University and former head of the Scientific IT Department at GSI. On the basis of his concept, data centers and commercial IT systems can today be operated with up to 50% less primary energy consumption in comparison to conventional data centers.

The first data center of this type was Goethe University's own, which was set up at the Infraserv industrial park at Frankfurt Höchst. Another, the Green IT Cube, was built by the GSI Helmholtz Center in Darmstadt. ❒

Metabolic engineering allows robust, standardized fermentation that is predictive at scale

Production of bio-based chemicals has important environmental, cost and functional benefits, but historical approaches have lacked robustness to the commercial process environment and have proven costly to develop. A platform technology developed by DMC Biotechnologies (Boulder, Colo.; www.dmcbio.com) was designed to standardize microbial fermentation, provide high-throughput approaches that predictably scale to commercial volumes, and to create biocatalysts that are robust under industrial process conditions.

DMC's patented technology, known as Dynamic Metabolic Control, effectively decouples the microbes' growth phase from production of the desired molecule in the fermentation vessel. "When the biocatalysts are grown, they are not producing any product," explains Matt Lipscomb, CEO of DMC Bio. "Once the desired biocatalyst concentration is reached, the microbes stop growing and begin producing a desired product."

This transition is achieved by genetically engineering the microbes' metabolic pathways with targeted proteolysis, gene silencing and other tools, such that an environmental trigger will change the expression of certain genes, shutting down those genetic elements that enable growth and expressing others that are responsible for making the product. "We grow the engineered microbes using a limiting macronutrient that, when depleted, triggers gene-expression changes that turn on the production pathway," Lipscomb says.

Re-writing the microbial genetics associated with growth and production allows the microbes to perform well under a broader range of process conditions, Lipscomb says, so "we don't have to do extensive process development at each scale." The fermentation is standardized in terms of feed, growth media and other parameters to optimize production.

The company is currently operating a pilot-scale process for producing specialty amino acids for the animal feed and human supplement markets, and plans to use its metabolic control technology to scale up fermentation processes for other products, such as organic esters for the personal care market, and terpenoids for the flavor and fragrances market. ■

Business News

Plant Watch

Mitsubishi Gas Chemical to build hydrogen peroxide plant in Taiwan

February 13, 2020 — Mitsubishi Gas Chemical Co., Inc. (Tokyo, Japan; www.mgc.co.jp) plans to build a hydrogen peroxide production facility in Taiwan to support the company's business for ultra-pure hydrogen peroxide used in semiconductor manufacturing. The new plant will produce 40,000 metric tons per year (m.t./yr) of hydrogen peroxide, and is expected to begin production in January 2023.

Kuraray to build PVA films plant in Poland

February 13, 2020 — Kuraray Co. (Tokyo, Japan; www.kuraray.com) will establish a new production facility for polyvinyl alcohol (PVA) water-soluble films in Zimna Wodka, Poland, as demand grows for packaging film for unit-dose detergents, pharmaceuticals and other products. The plant is slated to begin operation in mid-2022.

BASF announces new production site for battery cathode materials

February 12, 2020 — BASF SE (Ludwigshafen, Germany; www.basf.com) will build a new battery-materials production site in Schwarzheide, Germany, which will produce cathode active materials with an initial capacity enabling the supply of around 400,000 full-electric vehicles per year. The Schwarzheide plant's modular design and infrastructure allow for the rapid scaleup of manufacturing capacities. The plant in Schwarzheide will use precursors from BASF's previously announced plant in Harjavalta, Finland. Startup of the two plants is planned for 2022.

Indorama starts up ethylene cracker in Louisiana

February 4, 2020 — Indorama Ventures Public Co. Ltd. (IVL; Bangkok, Thailand; www.indoramaventures.com) has announced the commercial startup of its olefins gas cracker plant in Westlake, Louisiana. The site has an ethylene production capacity of 440,000 m.t./yr and is highly integrated within the U.S. Gulf Coast ethylene pipeline infrastructure. The facility is strategically positioned for longterm ethylene supply to Indorama Ventures' oxides and glycols plant in Clear Lake, Tex.

Celanese plans VAE expansions in China and the Netherlands

January 30, 2020 — Celanese Corp. (Dallas, Tex.; www.celanese.com) is starting a debottlenecking project at its Nanjing, China vinyl acetate ethylene (VAE) production facility. Celanese will expand VAE production capacity at this site by 65,000 m.t./yr by adding a third VAE reactor by late 2022, increasing the total Nanjing VAE capacity to 215,000 m.t./yr. Additionally, Celanese will further expand capacity at its VEA plant in Geleen, the Netherlands by 50,000 m.t./yr with an additional VAE reactor by early 2023, bringing the total Geleen VAE capacity to 200,000 m.t./yr.

BASF to expand capacity for polyurethane dispersions in Spain

January 23, 2020 — BASF has invested in expanding production capacity of water-based polyurethane dispersions at its Castellbisbal site in Spain. The expansion will allow BASF to increase its production capacity by 30% and will contribute to the transition from solvent-based coating systems to water-based systems.

Invista and Hengli Petrochemical start up fourth PTA line in Dalian

January 22, 2020 — Invista (Wichita, Kan.; www.invista.com) and Hengli Petrochemical (Dalian) Co. started up Hengli's fourth purified terephthalic acid (PTA) line, which can produce 2.5 million m.t./yr of PTA and is located in Dalian City, China. A fifth PTA line, identical to the fourth, is currently under construction at the same site and is expected to start up around the middle of 2020. Hengli currently operates three PTA lines at the site, each with a capacity of 2.2 million m.t./yr.

Mergers & Acquisitions

Ascend to purchase compounding and masterbatch businesses in Italy

February 12, 2020 — Ascend Performance Materials (Houston; www.ascendmaterials.com) signed an agreement to purchase Poliblend and Esseti Plast GD from D'Ottavio Group. The acquisition includes a manufacturing facility in Mozzate, Italy, the masterbatch portfolio of Esseti Plast GD and the engineering plastics portfolio of Poliblend, which consists of virgin and recycled grades of Nylon 66, Nylon 6, polybutylene terephthalate (PBT) and polyoxymethylene (POM).

Joint venture formed for production of bio-based levulinic acid

February 11, 2020 — Towell Engineering Group (Muscat, Oman; www.towellengineering.com) and GF Biochemicals (Geleen, the Netherlands; www.gfbiochemicals.com) formed a joint venture (JV) for the production and marketing of bio-solvents and bio-plasticizers based on levulinic acid, which is considered a key bio-based building block. GFBiochemicals' technology is said to be the first that enables production of levulinate derivatives at industrial scale.

LINEUP

ASCEND PERFORMANCE MATERIALS
BASF
CELANESE
CEPSA
DOMO CHEMICALS
GF BIOCHEMICALS
HENGLI PETROCHEMICAL
INDORAMA
INVISTA
J.M. HUBER
KURARAY
MASDAR
MITSUBISHI GAS CHEMICAL
NOURYON
PPG
SAIPEM
SOLVAY

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PPG to acquire Chicago-based powder-coatings manufacturer

February 6, 2020 — PPG Industries Inc. (Pittsburgh, Pa.; www.ppg.com) agreed to acquire Alpha Coating Technologies, LLC, a manufacturer of powder coatings for light industrial applications and heat-sensitive substrates. Alpha Coating Technologies is headquartered in West Chicago, Ill. The transaction is expected to close in the first quarter of 2020, subject to customary closing conditions.

DOMO acquires Solvay's European polyamides business

January 31, 2020 — DOMO Chemicals (Ghent, Belgium; www.domochemicals.com) has completed its acquisition of Solvay S.A.'s (Brussels, Belgium; www.solvay.com) Performance Polyamides business in Europe. This business includes engineering plastics operations in France and Poland; high-performance fibers in France; and polymer and intermediates operations in France, Spain and Poland. The purchase price paid by DOMO amounts to around €300 million.

Nouryon to acquire J.M. Huber's carboxymethyl cellulose business

January 30, 2020 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) has agreed to acquire the carboxymethyl cellulose (CMC) business of J.M. Huber Corp. (Edison, N.J.; www.huber.com). The acquired assets include a world-scale manufacturing facility, as well as an advanced research and development facility located in Äänekoski, Finland. CMC is bio-based water-soluble polymer that is used as a thickener, binder, stabilizer and film former.

Celanese to acquire Nouryon's Elotex polymer powders business

January 30, 2020 — Celanese intends to acquire Nouryon's redispersible polymer powders business offered under the Elotex brand. As part of the acquisition, Celanese will acquire all of Nouryon's global production facilities for redispersible polymer powders across Europe and Asia, all products under the Elotex portfolio, as well as all technology and commercial facilities globally.

Saipem acquires CO_2-capture assets in Canada

January 27, 2020 — Saipem S.p.A. (San Donato Milanese, Italy; www.saipem.com) acquired proprietary technology for CO_2 capture from the Canadian company CO_2 Solutions Inc. (CSI). Saipem has acquired CSI's portfolio of intellectual property, including over 90 patents. In addition, it has obtained the CO_2-capture plant located at a pulp mill in Saint-Félicien, Québec.

Masdar and Cepsa form renewable energy JV

January 21, 2020 — Renewable energy company Masdar (Abu Dhabi; www.masdar.ae) and Compañía Española de Petróleos S.A.U. (Cepsa; Madrid, Spain; www.cepsa.com) will establish a 50-50 JV company to develop renewable energy projects in Spain and Portugal. The new company, Cepsa Masdar Renovables, will focus on developing wind and solar photovoltaic projects in the Iberian Peninsula region. ■

Mary Page Bailey

Under Pressure to Perform Better

Developments in pressure relief technologies respond to chemical processors' need for improved reliability and safety

Pressure relief systems, whether rupture disks, pressure relief valves or other relief devices, are the last line of defense before a process enters a dangerous situation. "Processors never want pressure relief devices to activate, so it is important to take all possible steps to ensure that the process never gets to a state where this happens. However, if a pressure event does occur, you want to know that the device is reliably working and you want to be able to investigate the event effectively to ensure that it doesn't happen again," says Nick Petrosyan, customer success manager with TrendMinder (Houston; www.trendminder.com). This is especially true in the chemical process industries (CPI), where pressure relief events can have extremely hazardous and costly results. For this reason, pressure-relief-device providers are making improvements that increase reliability and safety of their wares, while new technologies are being introduced to help design, monitor and analyze pressure relief systems in an effort to investigate events and provide actionable information to avoid them.

GP Piping Systems

FIGURE 1. Pressure-retaining valve Type 586 and the pressure-reducing valve Type 582 from GF Piping Systems have been re-engineered to provide increased reliability and safety

Improved devices

The most commonly used pressure relief devices include pressure relief valves and rupture disks, which are designed to relieve pressure in a vessel or other process component when it reaches dangerous levels. Once activated, the devices release process fluids or gases to the environment or a closed recovery system. As the last line of defense, it is essential that they reliably operate in difficult chemical industry conditions.

While the basic operational design of pressure relief valves hasn't seen drastic changes, providers of the components say they are making improvements that increase reliability, especially in difficult environments like those found in the CPI. GF Piping Systems (Irvine, Calif.; www.gfpiping.com), for instance, re-engineered its Type 586 pressure-retaining valve (Figure 1). The new valve is compact, and easy to install and operate thanks to a set screw that controls a non-rising spindle for even flow control in order to maintain pressure reliably. The valve includes a threaded bonnet, which eliminates the need for body bolts, so there is no need to re-torque. This makes it suitable for aggressive media.

"We use a threaded, plastic-on-plastic design, which is significant in the CPI," says Jeff Sixsmith, product manager of valves and actuation with GF Piping. "Metals typically aren't good in a corrosive atmosphere or one where there is a hot line running at high temperatures. In these cases, when the line is shut down, the bonnet connection will no longer be tight because plastic and metal expand at drastically different rates and the connection is no longer secure. However, because our connection is plastic on plastic, we don't have that issue, so there's no need to re-torque the valves because the connection is still secure. This ensures reliable operation."

Farris Engineering (Brecksville, Ohio; www.cw-valvegroup.com/farris) recently began offering a restricted lift feature on its pressure relief valves, which allows users to customize the valve lift to meet specific capacity requirements. Restricted lift can improve a valve's performance and stability, says Sean Croxford, business unit manager of engineer-

Oseco

FIGURE 2. The Oseco Safety Cartridge combines the traditional three components of a rupture disc system into one hermetically sealed component to provide simplified installation for critical applications and guaranteed leak protection by removing the need to seal the rupture disc within a holder

ing services with Farris Engineering. "Typically when you size a relief valve, the valve will always flow more than what the application requires, but restricted lift valves can help reduce inlet losses and built-up back pressures, ensuring better, safer performance," he says.

Improvements have also been made on the rupture disc side. Oseco (Broken Arrow, Okla.; www.oseco.com) introduced its Safety Cartridge, which combines the traditional three components of a rupture disc system into one hermetically sealed component to provide simplified installation for critical applications and guaranteed leak protection by removing the need to seal the rupture disc within a holder (Figure 2).

"Rupture discs are designed to fail, but you don't want them to fail too early due to mishandling or improper installation," says Hunter Franks, chemical process segment engineer with Oseco. "Installation can be subjective. You have to clean and inspect the holder and then reinstall the disc. It is possible that not enough torque is applied or the holder is damaged or that it was installed incorrectly, which can lead to leakage. But this welded assembly is designed in such a way that it protects the disc, cannot leak and solves a lot of the installation issues that lead to premature failure."

Ameritrol

FIGURE 3. The FX Series flow switch from Ameritrol employs the thermal dispersion principle of operation, which features no moving parts for reliability

The importance of monitoring

"In the past, you had a relief device and it was there to protect the system from breaking or exploding, but what is happening now is that because of environmental and industry regulations, it's becoming far more common to monitor pressure relief devices so that you know there was an event," says Bob Klatt, manager, with Ameritrol (Vista, Calif.; www.ameritrol.com).

Andrew Cureton, wireless product manager with Emerson (Shakopee, Minn.; www.emerson.com) continues: "There's currently a rule for the [petroleum] refining industry that mandates the monitoring of relief valves, and our expectation is that it will cascade to other industries, including the chemical industry or any industry that releases hazardous materials, such as methane or VOCs [volatile organic compounds], into the environment."

But, there are reasons to monitor that go beyond compliance. "When a pressure relief valve activates, it's an indication that the process is out of specification of normal operation because these devices are not meant to release under normal conditions. So, when you have a release, it's an indication that something is wrong in the process," says Cureton. "Often an operator will know that something is upset, but because the control system that manages the process is designed to compensate for the upset or the release, the release goes unnoticed."

For example, if a boiler is feeding into a process and a downstream vessel releases, the control loop will kick up that boiler's output to offset the difference and final product will continue to come out. The process will still yield as much as before, but there will likely be quality issues or more waste in the process; however, operators will not know why this is happening if they don't know that they are releasing from a pressure relief device. Monitoring can help identify the cause of process upsets and process waste caused by pressure relief incidents that operators aren't aware of.

One of the simplest and most common ways to monitor pressure relief devices is via thermal dispersion flow switches, such as the FX Series flow switch from Ameritrol (Figure 3). The thermal dispersion principle of operation features no moving parts for reliability. The sensor head employs two temperature sensors with a constant, very-low-power heating source physically attached to one of the temperature sensors. The second temperature sensor is isolated from the heating source and provides compensation for changing process temperatures. As flow changes, so does the temperature differential. This allows the device to be used as a flow/no flow sensor. A dual switch point option allows two separately adjustable switch points to be set using the same instrument.

High-tech monitoring

At times, a pressure relief event is the only indication that a process upset has occurred and the sooner an event is detected, the sooner the root cause of the problem can be identified. Thanks to new sensing and software technologies, higher tech monitoring and root cause analysis is becoming easier.

Monitoring pressure relief devices provides real-time information, enabling users to pro-actively develop proper corrective action, optimize maintenance schedules and improve asset management while ensuring regulatory compliance.

For example, while rupture disks have been monitored for overpressure relief events for some time via the use of wireless sensors, pressure relief device providers, such as BS&B Safety Systems, LLC (Tulsa, Okla.; www.bsbsystems.com), realized that rupture disks often burst due to instantaneous and undetected

pressure spikes in the process. "Seldom is the pressure and temperature of a process monitored at the point of installation of the rupture disk and the monitoring systems previously used were not designed to transmit process data anywhere close to the frequency at which a rupture disk responds to overpressure," says David Garrison, business unit director for BS&B. "For this reason, many rupture disk activations are perceived to be caused by something other than a legitimate overpressure event. BS&B now offers equipment to monitor system pressure and temperature with a sampling resolution of up to 1,000 times per second, to which the rupture disk is exposed on the process side and the pressure on the downstream side. This system interprets and logs this information for subsequent use and analysis when a disk activates. The information can then be used by process engineers within the facility to help isolate the causes of the overpressue event."

Additionally, BS&B has a new sensor design available to warn users if a rupture disk device is damaged, installed improperly or when process conditions have exceeded design limits for a rupture disk device before the disk bursts, says Garrison. "This sensor is used in a predictive role to anticipate condition and serviceability of the disk. It measures the strain applied to a rupture disk while in service and compares actual strain to a baseline determined during the manufacture of that specific rupture disk," he says. "Strain values, outside of the known norm for that rupture disk device, indicate a risk of activation outside of tolerance, allowing it to be replaced before a nuisance activation occurs."

The development of these rupture disk sensors has rapidly moved the "dumb" technology to contemporary "smart" technology with data gathered from advanced sensor signals capable of producing information useable for operators to plan on necessary rupture disk replacement at a convenient time, he says.

On the pressure-relief-valve side, Emerson offers the Rosemount 708 wireless acoustic transmitter (Figure 4). The device mounts externally and features ultrasonic acoustic event detection to allow visibility into steam traps and pressure relief

Emerson

FIGURE 4. The Rosemount 708 wireless acoustic transmitter features ultrasonic acoustic event detection to allow visibility into pressure relief valves by communicating acoustic level and temperature data, as well as device data, event status and leak detection via the WirelessHART network

TrendMinder

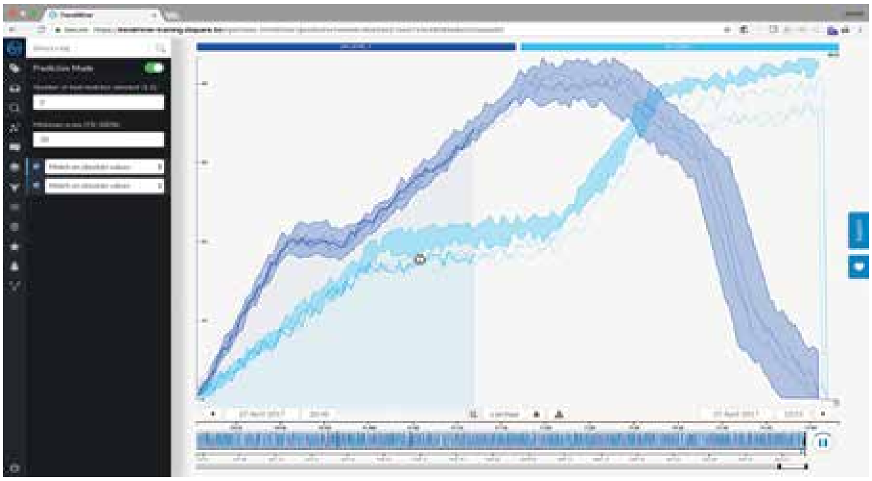


FIGURE 5. **TrendMinder offers analytical software that indexes data from a historian and provides multiple ways to search for abnormal patterns, relevant events or time frames within historical process or asset data. It can be used to prevent repeated production issues by monitoring live processes and sending automatic notifications in the event of deviations, based on predefined settings to provide early warnings on process behavior**

valves by communicating acoustic level and temperature data, as well as device data, event status and leak detection via the WirelessHART network. To make the data provided by the sensor more actionable, it is tied into Emerson's Plantweb Insight software platform. "This makes it a more complete solution and brings pressure-relief-valve monitoring into the world of pervasive sensing and the IIoT," says Emerson's Cureton. "The data coming from the sensor can be a little crude, but the software analytics of Plantweb Insight make sense of the data coming out of it. The software detects releases, alerts users on it and logs the duration in a way that can help create a report."

The important value here, he says, is that when there are VOCs or other hazardous chemicals released that need to be reported, you can accurately report the releases rather than being dependent on the time of the last inspection. "Typically, if you have a release and it has been detected, the Environmental Protection Agency will fine the facility for the time between detection and last inspection, which, for pressure relief valves that are hard to reach, can be days or weeks and this can result in huge fines," he says. "There can be a huge delta between a momentary release and something that's been sustained."

Further, monitoring and analyzing data can be helpful in other ways. "We are able to look for patterns of behavior and associate rises and falls with issues with the process. It is also able to identify which valve is releasing, helping to identify and correct the source of the release sooner," explains Cureton.

Similarly, TrendMinder offers analytical software that indexes data from a historian and provides multiple ways to search for abnormal patterns, relevant events or time frames within historical process or asset data (Figure 5). It can be used to prevent repeated production issues by monitoring live processes and sending automatic notifications in the event of deviations, based on predefined settings to provide early warnings on process behavior.

Using time series data collected from temperature gages, pressure gages, flowmeters and other sensors, users can ask the software things like "How many times have I exceeded this pressure threshold while producing this product?"

"By examining these patterns and creating monitors based on patterns, you can find early indicators that a relief event may occur," says TrendMinder's Petrosyan. "If pressure swings or pressure or temperature oscillations usually precede a pressure event, you can capture those patterns inside TrendMinder and use them to generate new types of monitors that will alert you when something is about to happen."

Further, he says, the software helps with incident investigation. "Processors try to design processes and plants to be safe and if you're constantly exceeding key safety limits, then something is wrong," he says. "Typically when there is a relief event, there is a release investigation that involves data analysis, looking through historical data and studying the sequence of events that led to the pressure excursion. This type of analytical software makes it easier to do a good job with the investigation because it looks at all the available data, which helps users determine the appropriate corrective actions necessary to make the plant safer and to prevent the event from happening again."

And, to ensure that the pressure relief system is properly designed, to avoid potential incidents and comply with current regulations, Farris Engineering has created iPRSM, a solution for the design, audit and documentation of new and existing pressure relief systems. The web-based software provides a comprehensive approach to the management of pressure relief systems for safety compliance. It facilitates the evaluation of protected systems, systematically identifying problems and providing plant management with the critical tasks needed for overpressure protection compliance. The analysis capability acts as an effective management-of-change system and all reports and documentation necessary for regulatory purposes can be produced from iPRSM.

"This helps improve equipment and plant reliability, minimizing downtime and production losses related to overpressure events," says Farris' Croxford. "We are able to tie devices into this software and log events to provide actionable information back. Because it's web enabled, one of our experts can look at any issues the clients may be having and assist them with taking the right course of action. It is like having an expert next to you while doing calculations. We put a lot of time and energy into providing subject matter expert advice to our clients and into helping them make their plants safer, more effective and within compliance." ■

Joy LePree

Focus on Corrosion Protection

Simplified access to corrosion-monitoring data

In January, this company introduced the Plantweb Insight Inline Corrosion application (photo) to provide the oil-and-gas industry real-time interpretation and analysis of critical data that helps prioritize maintenance and make informed integrity decisions. The Plantweb Insight Inline Corrosion application delivers field data from Roxar wireless corrosion transmitters, providing insight into instrument health and process corrosivity. It offers alerts on preset thresholds for severe corrosivity, probe lifespan for electric resistance (ER) probes, low battery levels and more. The easy-to-read dashboard displays an intuitive heatmap with intelligence on corrosivity of fluid levels based on the NACE standard. This latest industrial internet of things (IIoT)-based application seamlessly integrates into existing wireless infrastructures and delivers field data as frequently as once every 15 minutes. — *Emerson, Stavanger, Norway*
www.emerson.com

GRP shelters protect offshore process analyzers

Shelters fabricated from glass-fiber-reinforced polyester (GRP) are protecting gas metering instrumentation from the harsh North Sea environment on an offshore platform-upgrade project engineered by Oil & Gas Systems Ltd. Two outdoor shelters — supplied by this company — provide lightweight and corrosion-resistant protection for gas chromatograph analyzers and process transmitters mounted above new natural gas export pipelines connecting the platform to an onshore U.K. terminal. GRP materials were specified to protect the instrumentation. This allowed weight to be reduced significantly compared with metal shelters. GRP construction also provided excellent protection against both the harsh weather in the offshore location, and the local environmental conditions. The lightness of GRP compared to steel helped to reduce the size and weight of the metalwork structure that mounts the shelters directly above the export pipelines. All of the shelter fittings, apart from the finned aluminum bodies of the heaters, are fabricated from 316 stainless steel for corrosion resistance — including the panic-bar door opening mechanism. — *Intertec Instrumentation, Sarnia, Ont., Canada*
www.intertec.info

New powder coatings for protecting steel

This company's new Interpon Redox range of powder coatings provides a simple route to maximum corrosion protection. It covers a full array of substrates, surfaces and environments — from cable cars and chemical plants to window frames and wind turbines. Long-term performance is paramount for specifiers, who rely on finding the right corrosion protection system for their steel products. However, the process of selecting the right system is influenced by various factors, such as the material used, the environment it is exposed to and how quickly it is likely to corrode. The company helps to simplify this decision-making process and offers users reliable corrosion protection, in all conditions. Already available in Europe, Interpon Redox will be launched this year in Asia and North America. — *AkzoNobel Powder Coatings B.V., Amsterdam, the Netherlands*
www.interpon.com

A power supply for advanced cathodic protection

The DCPro (photo, p.18) is an advanced cathodic-protection power supply. The DCPro is a significant improvement to the way traditional rectifiers convert a.c. to d.c. power when used in cathodic protection systems. With the DCPro, advanced technology provides a durable power supply that offers efficient, pure d.c.power while eliminating manual operations that have caused frustration with the use of conventional rectifiers. The

Emerson

Intertec Instrumentation

Note: For more information, circle the 3-digit number on p. 50, or use the website designation.

Farwest Corrosion Control

Olympus

Cortec

power supply eliminates the need to manually adjust power output for cathodic protection systems. This can be accomplished reliably with the turn of a single knob. Corrosion control and the need for cathodic protection solutions continue to be essential for pipelines, storage tanks and other underground and underwater structures as they age. — *Farwest Corrosion Control Co., Downey, Calif.*
www.farwestcorrosion.com

Handheld XRF analyzer offers fast material identification

The new Vanta Element X-ray fluorescence (XRF) analyzer (photo) offers speed, reliability, ruggedness, connectivity and smartphone-like ease of use in a cost-effective handheld model. The Vanta Element analyzer is suitable for use in corrosion detection, scrap recycling and metal manufacturing. Users can obtain clear material and grade identification in seconds and compare alloy grades on the instrument's screen. With a dual-core processor and powered by the company's proven Axon Technology, the Vanta Element analyzer has the same stability and resolution as the rest of the Vanta series for rapid sorting and a fast ROI. Built for use in demanding environments, Vanta Element analyzers are IP54-rated for resistance to dust and moisture and constructed to pass a 4-ft drop test (MIL-STD-810G) to help keep you working in case of an accidental drop or impact. For additional protection, a stainless-steel faceplate is paired with a thick (50 μm) Kapton window that can be easily attached and removed for toolless window changes in the field. — *Olympus Corp., Waltham, Mass.*
www.olympus-ims.com

A perfect team for eco-friendly corrosion protection systems

The unique combination of a waterborne zinc-rich primer (Dynasylan SIVO 140) and an ultra-high solid siloxane-hybrid binder (Silikopon EF) formulation combines the most effective corrosion protection (C5 Class) with easy handling in just two layers. This highly effective partnership of perfectly adjusted binders leads to higher productivity by improved curing speed and lower total film thickness. Total costs can be significantly reduced by this two-layer system. Furthermore, it only releases 20 g/m^2 of volatile organic compounds (VOCs). The waterborne binder Dynasylan SIVO 140 was especially designed for use in two-pack zinc-dust paints for application in areas that require heavy-duty corrosion protection (for instance, for overhead power-line utility poles, bridges, exterior ship hulls and industrial facilities). Silikopon EF is a siloxane-epoxy hybrid resin suitable for ultra-high solids, eco-friendly coatings for gloss, color retention and weather resistance during outdoor use. Of particular significance is that it permits the production of non-isocyanate curing two-pack formulations with a very low-VOC content. Silikopon EF allows two-coat corrosion-protection coatings, which can replace the classic three-coat systems by reducing costs for application and total material consumption at the same time. — *Evonik Industries AG, Essen, Germany*
www.evonik.com

A deep-reaching solution for corroding rebar

Mitigating corrosion of embedded rebar is a perennial problem for reinforced-concrete structures, requiring preventative maintenance and repair. Topical corrosion-inhibiting treatments require a clean, properly prepared surface area to work as intended. MCI-2020 Gel is designed to work when proper surface preparation cannot be achieved or is economically undesirable, by delivering the company's proven Migrating Corrosion Inhibitor (MCI) technology directly to the depth of reinforcement (photo). MCI-2020 Gel is an injectable corrosion inhibitor that provides a robust dose of corrosion protection directly where it is most needed. Once inside the concrete, the inhibitor can also move laterally through the concrete along the embedded reinforcement via liquid and vapor diffusion. MCI molecules deposit across metal surfaces, forming a molecular layer that acts as a barrier to corrosive elements, such as chlorides and carbonation. — *Cortec Corp., St. Paul, Minn.*
www.cortecvci.com

Corrosion protection for steel reinforcement

MasterProtect 8500 CI is a new corrosion inhibitor developed by this company's scientists after years of research and tests to enhance and complement the broader refurbishment and repair portfolio for concrete. MasterProtect 8500 CI is a dual-function, silane-based corrosion inhibitor that can be applied to the surface of all types of reinforced concrete structures — both new and existing — without changing the appearance of the concrete. The dual functionality of MasterProtect 8500 CI separates it from existing inhibitors, because its unique blend of high-quality silanes, combined with selective corrosion inhibitors ensures long-term protection of the concrete structures, extending their service life. The unique added value of MasterProtect 8500 CI is that it ensures protection also in the case of post-application cracks, as proven by various independent tests. In addition, MasterProtect 8500 CI has a very low viscosity to improve penetration into the concrete over a wide temperature range, a lower VOC content and a higher flash point. — *BASF SE, Ludwigshafen, Germany*
www.basf.com

Sustainable surface treatment for aluminum processors

Bonderite M-NT 65000 was originally developed for aluminum alloy components (photo) for the aerospace industry and sets new benchmarks for corrosion protection, paint adhesion and low electrical-contact resistance. As a REACH compliant, nontoxic labeled and hexachromium-free conversion product, it offers a convenient, efficient and sustainable alternative to conventional Cr^{+6}-based aluminum surface-treatment processes. Bonderite M-NT 65000 can be used with standard equipment, requires no filtration and no post-treatment. — *Henkel AG & Co. KGaA, Düsseldorf, Germany*
www.henkel.com

Henkel

A new coolant with engine corrosion protection

Introduced last month, WT SUPRA Coolant is an environmentally friendly inhibitor concentrate based on a patented carboxylate technology that delivers extended service life and superior corrosion protection in engines. The product has been specifically designed for use in marine two-stroke, four-stroke and stationary engines, as well as smaller, high-speed auxiliary engines. WT SUPRA contains no inorganic ingredients, such as phosphates, nitrates, amines, boron or silicates. — *Total Lubmarine, Nanterre, France*
www.totallubmarine.com ■

Gerald Ondrey

New Products

Siemens Digital Industries

Edwards Vacuum

Sensorex

Val-Matic

Ultra-compact weighing electronics for precision

The Siwarex WP351 (photo) is one of the smallest electronic weighing units available, measuring just 20 mm (width) by 65 mm (height). The device's 1,000-Hz sampling rate and processing time, combined with a digital output response time of less than 1 ms, guarantee high accuracy and repeatability. This capability is especially advantageous for checking scales and high-performance filling machines, as even within very short weighing times, the dosing devices are optimally controlled. As an integral part of Simatic ET 200SP, Siwarex WP351 can be seamlessly integrated into Simatic and non-Simatic automation systems. The intelligent firmware gives users the ability to control weighing processes directly from the module, thereby reducing the load on the connected programmable logic controller (PLC). — *Siemens Digital Industries, Nuremberg, Germany*
www.siemens.com

These liquid-ring pumps feature two drives

The ELRi range of liquid ring pumps (photo) is designed for use in applications that are wet, humid and corrosive. The stainless-steel impeller, endplates, liquid reservoir and heat exchanger make this pump highly resilient against corrosion and harsh process gases. The internal injection channels reduce the risk of leakage while the horizontal motor-flange arrangement saves time on maintenance. ELRi pumps are equipped with two variable-speed drives (VSDs). While the main VSD matches the speed of the pump to vacuum level by adjusting its speed, the second VSD regulates the water flow through the centrifugal pump according to the operating conditions to avoid risks of cavitation. A patented algorithm maintains synchronicity between the two VSDs. In addition, pumps are protected against automatic seizure, so pump failure is not a concern after long periods of inactivity. The ELRi series is available with pumping capacity from 750 to 1,050 m^3/h. All pumps are also fitted with spray nozzles as standard, which are particularly useful for high-steam-load applications. Moreover, manual and automatic flushing modes allow operation in dirty applications with minimal downtime. — *Edwards Vacuum, Burgess Hill, U.K.*
www.edwardsvacuum.com

Conductivity sensors designed for ultra-pure water

The CS700 stainless-steel conductivity sensor (photo) covers a wide variety of applications, but is particularly effective with ultra-pure water. The sensors offer an adjustable insertion length to fit any installation type. The sensors are constructed of heavy-duty 316 stainless steel and Teflon to enable installation in difficult applications. Sensor accuracy is 2% of reading with 0.1% repeatability when properly calibrated. The sensor's electro-polish finish promotes stability and consistency. The CS700 withstands temperatures up to 150°C (302°F) and pressures up to 200 psig. — *Sensorex, Inc., Garden Grove, Calif.*
www.sensorex.com

Rugged ball valves for all types of water-treatment processes

The Ener•G ball valve (photo) is designed for municipal and industrial water and wastewater applications. The valve is also suitable for various pump-control needs. Valves feature equal-percentage flow characteristics, rugged construction (meeting American Water Works Association standards) and negligible head loss. When fully open, the Ener•G ball valve provides 100% flow area equal to the pipe size and can present significant savings in pumping costs compared to other pump control valves, says the manufacturer. The valve is available with cylinder, electric motor or manual actuation. — *Val-Matic Valve & Manufacturing Corp., Elmhurst, Ill.*
www.valmatic.com

A comprehensive digital platform for chemical data discovery

Chemtiva is a new digital platform that is designed to help users make informed decisions regarding commercial feasibility, compliance and safety of products. Chemtiva integrates leading scientific and commercial information into a single platform

addressing information and data needs and supporting cross-functional collaboration between R&D, scaleup and environmental, health and safety (EHS) functions. Chemtiva utilizes proprietary domain-specific taxonomies, ontologies and data-science technologies to normalize and aggregate critical information from the global scientific literature, toxicological reports and EHS regulations, with market-relevant information, such as global shipments, technical datasheets and industry news, enabling access to over 13 million substances, 7 million products and 17,000 suppliers. Chemtiva aggregates research, toxicology, safety, regulatory, reaction and commercial data from millions of datasets, enabling users to instantly access, visualize and share the data their teams need to drive accurate decision-making throughout the product lifecycle. — *Elsevier B.V., Amsterdam, the Netherlands*
www.elsevier.com

New level switches to optimize operations in solids applications

The new range of Rosemount solids level switches (photo) was designed to increase safety and reduce waste by providing reliable point-level monitoring and supporting overfill prevention. The vibrating fork, paddle, capacitance and vibrating-rod switches monitor solid materials, such as powders, grains and pellets, in all silo types. The compact switches require low levels of maintenance and are suitable for operation in extremely challenging environments, including those with high temperatures, high pressures, dust and risk of explosion. The switches can be used to provide standalone point-level monitoring to help optimize filling and emptying cycles. They can also be deployed within an overfill-prevention system. — *Emerson Automation Solutions, Austin, Tex.*
www.emerson.com

New device delivers UV/IR sensing for hydrogen detection

The FL500-H_2 (photo) is an ultraviolet/infrared (UV/IR) flame detector designed specifically to detect hydrogen fires. The FL500-H_2 sensors monitor optical radiation emitted by a hydrogen flame in both the UV and IR spectral ranges while simultaneously rejecting nuisance false-alarm sources that are common within industrial job sites. The detector's flame-sensing technology relies on the UV sensor to provide a quick response (<3 s) and the IR detector monitors radiation emitted by a flame over a wide 130-deg field of view. UV/IR sensor technology offers increased immunity, operates at faster speeds, and is suited for both indoor and outdoor use. The detector's design features a compact footprint for ease of installation, along with a rugged stainless-steel housing. The easy-to-read display includes three LED indicators that show normal operation, fault condition and an alarm. — *MSA Safety, Cranberry Township, Pa.*
www.msasafety.com

Hose adapters designed for maximum product safety

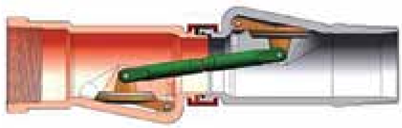
This company's Break-Away adapter (photo) is a break-away coupler designed with an engineered break-point to protect plants, tanks, trucks, rail-cars and loading arms from the hazardous consequences of pull-away incidents. The patented design does not restrict flow of product and requires no annual maintenance. The company has also released 2- and 3-in. cryogenic Break-Away hose assemblies. This assembly is designed to protect cryogenic facilities from catastrophic hose failures and pull-away incidents. The Smart-Hose cryogenic hose assembly, a passive safety device, requires no human intervention to activate. — *Smart-Hose Technologies, Folcroft, Pa.*
www.smarthose.com

Dependable shutoff in severe service

Clampseal throttling valves (photo) are appropriate for use in severe-service applications that require precise repeatable flow control and dependable shutoff. The valve's Venturi is an integral part of the removable seat. Both the seat and the stem assembly are easily changed inline should modified flow characteristics be required or replacement necessary due to excessive corrosion or erosion. The orifice is sized to keep fluid velocity across the seat below damaging levels. The exit orifice angle is designed to minimize downstream piping erosion and noise. The

Emerson Automation Solutions

MSA Safety



Smart-Hose Technologies

Conval

Valley Forge & Bolt Mfg.

Endress+Hauser Group

R. Stahl

pressure-seal bonnet provides ready access for servicing with no welds to cut or seal rings or gaskets to replace. The body-to-bonnet joint integrity is maintained through countless thermal cycles. The durable, single-piece stainless-steel gland contributes to the longevity of the valve. — *Conval, Enfield, Conn.*
www.conval.com

Interpret clamp load within bolts, and monitor remotely

Knowing the tension of critical joints is essential to safety, performance and maximizing uptime. SPC4 load-indicating technology (photo) makes it possible to measure the actual tension in a fastener, not just the preload that is being applied by torque or tension tools. By using SPC4 and any one of its specially designed interchangeable readers, technicians can quickly and easily gage tension and even have the option of remotely monitoring fastener tension within SPC4 bolted joints. SPC4 is ASTM F2482 compliant, and accurately measures direct tension in the fastener within ±5%. It provides absolute, realtime knowledge of fastener tension and performance — from installation through the full fastener life. SPC4 measures the stretch of the bolt (in other words, the bolt tension), directly from the fastener. Because stretch is the force that creates clamp load, this capability makes SPC4 the most accurate method available to monitor the clamp load of critical joints, says the company. — *Valley Forge & Bolt Mfg. Co., Phoenix, Ariz.*
www.vfbolts.com

Two new point-level instruments recently introduced

The Liquiphant FTL51B and FTL41 vibrating-fork (vibronic) level instruments (photo) were recently launched. The FTL51B features Industry 4.0 and industrial internet of things (IIoT) capabilities, including access via wireless Bluetooth technology, automatic proof tests and verification, and easy commissioning via a mobile device. In addition, operational clarity is provided by a high-visibility LED. The Liquiphant FTL51B can be used in storage tanks, containers and pipes for point-level detection of all types of liquids. The instrument's vibronic sensor is not affected by changing media properties, flow, turbulence, gas bubbles, foam, vibration or buildup. The instrument works in process temperatures of –58 to 302°F and pressures up to 1,450 psi. It can be used in SIL2 and SIL3 hazardous locations, and has built-in automatic maintenance and verification functions. The general-purpose FTL41 works at lower pressures, up to 580 psi, and with a narrower temperature range of –40 to 302°F. Both perform proof tests, with the FTL51B meeting SIL and WHG (Water Resources Act) requirements. The proof test can be activated remotely at a control system, or locally via a magnet or pushbutton test. The proof test diagnoses the sensor for corrosion and buildup, and ensures that the entire instrument is operating properly. — *Endress+Hauser Group, Reinach, Switzerland*
www.endress.com

These luminaires have a DALI interface

This company has expanded its product range, adding modern explosion-protected lighting systems equipped with Digital Addressable Lighting Interface (DALI; photo). The new EXLUX variants correspond to the DALI standard according to IEC 62386 and are specifically designed for consistent lighting management for general and emergency lighting, even up to Zone 1 explosion protection. As well as safety and emergency lighting, the range includes durable, energy-efficient linear luminaires that can be installed as ceiling, pendant or pole-mounted light fittings. These luminaires, from the EXLUX 6002/4, 6402/4, 6009/4 and 6409/4 ranges, are designed to function for over 100,000 operating hours at a maximum ambient temperature of 60°C. Thanks to the use of bidirectional DALI communication, around 200 programmable commands can be configured, allowing operators to set different intensity values and dimming behavior for individual light fittings or luminaire groups. — *R. Stahl, Waldenburg, Germany*
www.r-stahl.com ■

Mary Page Bailey and Gerald Ondrey

Distillation: Column Trays and Packing

Department Editor: Scott Jenkins

Industrial distillation columns use either trays or packing to promote vapor-liquid contact in separating the components of liquid mixtures to the desired purity. Approximately one half of columns are equipped with trays globally, and the other half contain packings. This one-page reference reviews the differences between the two and the process situations that lend themselves to one or the other.

Column trays

As a liquid mixture is heated in an industrial distillation column, the vapor generated is more concentrated in the lower-boiling (more volatile) material, while the liquid is more concentrated in the higher-boiling material. By harnessing this principle, distillation columns can separate components of mixtures. Stacks of metal trays, oriented horizontally across the column's interior, are designed to hold up liquid while the rising vapor flows upward. The trays have openings to allow vapor to flow upward through the column, as well as conduits (downcomers) to allow condensed liquid to flow downward (Figure). The tray is designed to promote intimate contact between the upward-moving vapor and downward-moving liquid. Each tray effects a portion of the separation before the vapor and liquid move to the next tray in the column until the desired concentrations (purities) are reached. Common types of trays include bubble-cap trays, valve trays, and sieve trays.

Column packing

Rather than a stack of discrete trays providing vapor-liquid contact, distillation columns facilitate liquid-vapor contact by filling the interior of the column with packing materials designed to provide a large surface area per unit volume. As the liquid phase flows through the tower, the vapor and the liquid are in continuous contact on the surfaces of the metal, ceramic or plastic packing. Packed towers are generally in one of two forms: random packing and structured packing. Random packing consists of small units of high-surface area shapes that are dumped into a column and allowed to settle. Structured packing is made from corrugated sheets of perforated metal, plastics or wire gauze, and is fixed in place. Structured packing is designed with high surface-area-to-volume ratios, and to maximize liquid spreading. At the same time, they try to maintain low resistance to flow. Both random-packed towers and structured-packed towers require liquid distributors at the top of the column and packing support plates at the bottom of the column.

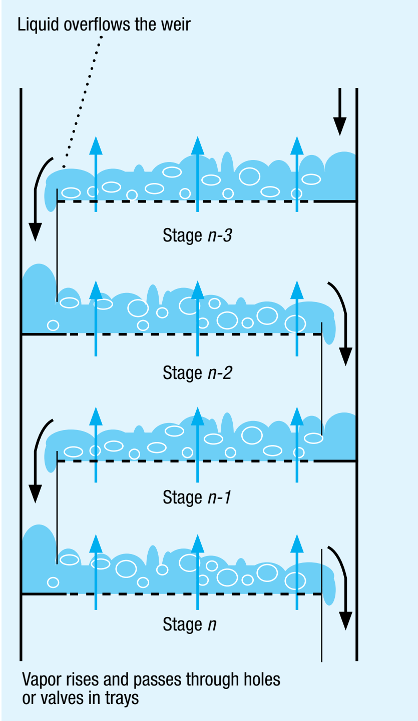
Advantages and disadvantages

Trayed columns and packed columns have key advantages and disadvantages, including the following:

- Packed towers are more effective when used with corrosive liquids
- Packed towers handle foaming systems better than trays
- Packings provide extra interfacial area for liquid-vapor contact, so the efficiency of the separation is increased for the same column height
- Packed columns can be shorter and more cost-efficient than trayed columns
- Random packings are easier to install than trays and structured packing
- Optimal performance of packed columns require effective liquid distributors feeding the packed bed
- Tray towers offer better predictability than packed towers
- Tray towers are better at handling solids
- Tray towers are better at handling lower liquid rates

Pressure drop. When compared to trays, the biggest advantage associated with packings is lower pressure drops. This is particularly true with columns that are operating at pressures below atmospheric. Generally, the pressure drop across a bed of structured packing is about one-sixth of that across a stack of trays having the same total height.

High pressure. There are situations where packing is less applicable, such as high-pressure distillation columns, where pure products are being targeted. Trays perform better in those cases, and much more predictably, in such columns where the volumetric liquid-to-vapor ratios are high.



Fouling. Fouling is a challenge for all column types. With trays, parts can become plugged and lose the ability to pass liquid or vapor. With packings, liquid distributors can become plugged, making distribution suboptimal. Structured packings are much more prone to fouling than random packings, because the metal sheets of structured packings are tightly spaced.

Revamps. Over time, vendor companies developing new tray and packing geometries have improved the performance of these products. New generations of trays, random packings and structured packings have made it possible, at times, to substantially improve column performances with relatively easy column revamps. When trays replace packings, it is usually because the packing performance has been disappointing. When packing replaces trays, it is usually in pursuit of reduced pressure drops. ■

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Polyoxymethylene Production

By Intratec Solutions

Polyoxymethylene (also known as POM and polyacetal resin) is a thermoplastic polymer fiber. Owing to its crystalline structure, consisting of organized stacking chains, POM has high strength, stability, stiffness and hardness, as well as low friction. These characteristics, combined with chemical resistance and excellent dimensional stability, make the polymer a common substitute for metal. It is widely used in the manufacturing of high-performance engineering materials and electronics.

The process

The process examined here (Figure 1) is a conventional silver-catalyzed process with a methanol recycle, combined with a polymerization process. It consists of three major sections: (1) partial oxidation; (2) formaldehyde purification; and (3) polymerization.

Partial oxidation. Fresh methanol and air are fed to an evaporator, and the resulting vapor is mixed with steam and sent to a reactor, where the methanol is partially oxidized in the presence of a catalyst bed of silver crystals, yielding a formaldehyde solution and hydrogen. The hydrogen gas generated is also burned, with water as the only product.

Formaldehyde purification. The reactor effluent is fed to an absorption column. Methanol and formaldehyde are absorbed and sent to the methanol stripper. This stripper separates unreacted methanol, which is recycled to the reactor, from formaldehyde, which is routed to an ion exchanger and then to a concentration column. The concentrated formaldehyde is sent to an extraction column, forming hemiformal by contact with cyclohexanol. A cyclohexanol-water mixture is routed to a decanter to recover cyclohexanol. The hemiformal is sent to the pyrolysis area, where it is cracked to split off the formaldehyde monomer, which is directed to the polymerization reactor.

Polymerization. Formaldehyde is fed to a reactor and polymerized into POM, which precipitates as it is formed. The solid particles are separated from the solvent in a vacuum filter, are dried to remove volatile materials, and routed to the acetylation reactor, where hydroxyl groups on the polymer chain are converted to acetate groups. The product from the acetylation reactor is routed to a hot nitrogen dryer to remove residual acetic anhydride, which is recycled to anhydride recovery. The acetic anhydride stream is recovered, refined and recycled to the acetylation reactor. The dried product is then sent to an extruder, to blending silos, and it is then packed and stored.

Production pathways

Polyoxymethylene production can occur by the homo- or co-polymerization of formaldehyde, which can come from different raw materials. In this context, typical POM production routes are based on formaldehyde production (via catalytic oxidation of methanol). Different pathways for polyoxymethylene production are presented in Figure 2.

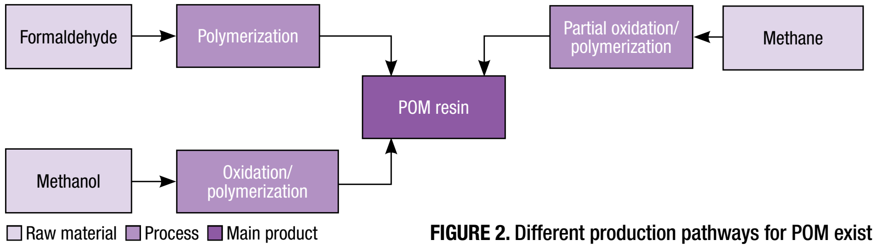

FIGURE 2. Different production pathways for POM exist

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce polyoxymethylene was about $1,870 per ton of polyoxymethylene in the first quarter of 2016. The analysis was based on a plant constructed in the U.S. with capacity to produce 85,000 metric tons per year of POM.

This column is based on "Polyoxymethylene from Methanol and Acetic Anhydride – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/polyoxymethylene-production-cost. ■

Edited by Scott Jenkins

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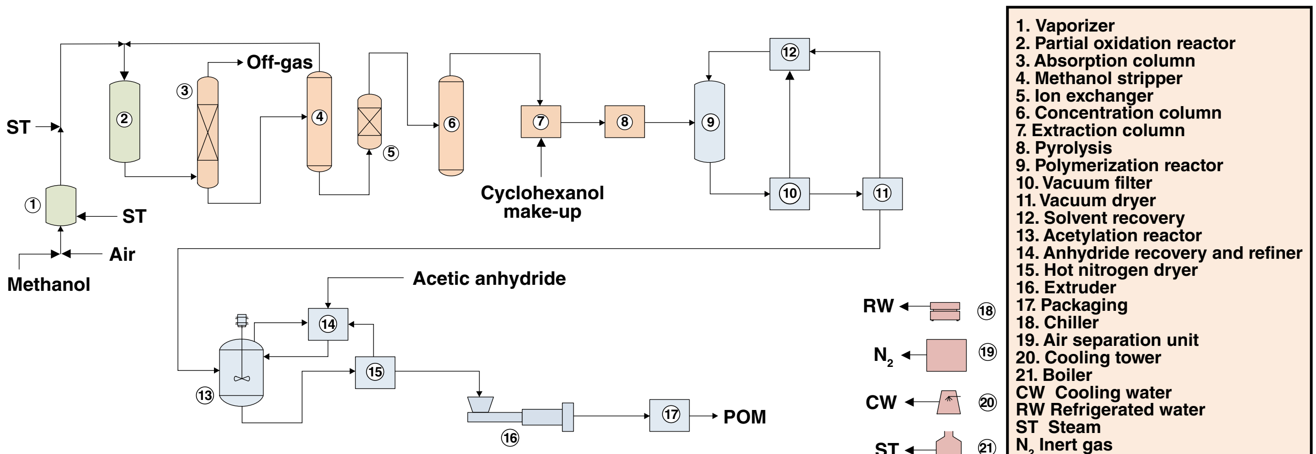

FIGURE 1. The diagram shows the production of polyoxymethylene, a thermoplastic fiber

Sustainability Snapshot: Making Practical Progress

In their own words, sustainability leaders from the chemical process industries provide insight about their practical success and ongoing goals in improving environmental performance

Considerations about environmental sustainability are permeating all levels of the global economy, as companies realize that change is necessary for the resilience of their businesses, as well as society as a whole. Indeed, the activities of the chemical process industries (CPI) have traditionally involved the consumption of non-renewable resources and in many cases, the generation of large amounts of atmospheric emissions, but the materials produced by the CPI are also essential to countless products across global supply chains. This article outlines some of the practical progress and ongoing work of the CPI toward advancing sustainable manufacturing practices.

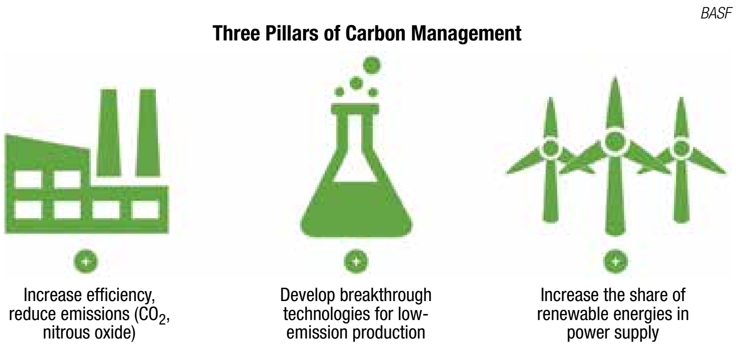

FIGURE 1. Major drivers for sustainable innovations include reducing CO_2 emissions, waste production and the consumption of energy and water

IN BRIEF

DEFINING THE CIRCULAR ECONOMY

MAKING SUCCESS MEASURABLE

FEEDSTOCK EFFICIENCY

OPERATIONAL AND ENERGY GAINS

THE PLASTICS PROBLEM

"If we accept that the human impact on the environment and climate has to be addressed, then every aspect of life will have to change in some way," says Ron Gerrard, corporate sustainability officer at Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com). "The science of chemistry and the chemical industry itself are major sources of potential solutions to address many of these needs. But we are not complacent, and we recognize we will also need to change and adapt our feedstocks, energy sources, technologies and supply-chain solutions in the decades ahead," he emphasizes.

The adoption of sustainable practices is not simply a compulsory action dictated by government regulations — the transition to more sustainable manufacturing models is complex, and also opens the door for paradigm-shifting innovation in the CPI and beyond. "We need to work across the value chain in collaboration with other industries and governments, if the right policies, funding, infrastructure and innovation are to be delivered," continues Gerrard. At this stage, he points out that sustainability momentum is continuing to build, but that in many cases, the steps being taken in the CPI are self-initiated and somewhat independent. However, as the sustainability interests of consumers, manufacturers and regulatory bodies coalesce, the transition will rapidly accelerate. "Growing consumer and media attention, coupled with new regulatory drivers, are prompting companies to take a closer look at how the drive for a more circular economy may impact their strategy. With the right support, collaboration, incentives and adjustment to consumer demands and expectations, the industry will be capable of much more to support global sustainability and the development of a real circular economy in the years ahead," adds Gerrard.

Defining the circular economy

With a unique position in the global supply chains of countless products, the CPI are poised to be a critical part of the ongoing push toward more circular, sustainable products and processes. "The chemical industry and its innovations will be crucial to drive change, since chemistry plays a key role in many value chains of the mobility, packaging, construction and agricultural industries. By

developing circular approaches with different industries, the chemical sector can contribute more to circularity," says Mitchell Toomey, director of sustainability, BASF Corp. (Florham Park, N.J.; www.basf.com). Toomey describes the circular economy as "moving away from the linear model of 'take-make-dispose' to a system of closed loops powered by renewable energy."

To realize this model, companies must take action at all levels. From ambitious measures to decrease atmospheric emissions and reduce resource consumption to designing new products and processes with circularity and renewable energy in mind, CPI companies are actively working toward improving their environmental footprint (Figure 1). "Circular economy solutions require more durable and more resource-efficient products, as well as new business models to support an increase in reuse, repair and recycling," says Toomey.

"We believe that our future license to operate and by extension, commercial success, depends on ensuring that all parts of our portfolio are driven by the transition from a linear to a circular economy," says Tony Kingsbury, director of sustainability EMEA, Dow (Midland, Mich.; www.dow.com). In the case of plastic, its low cost and ease of use have become environmental liabilities in many applications, says Kingsbury: "Plastic's everyday presence in our lives means we often take it for granted, resulting in it being too easy to use and then needlessly thrown away." According to Kingsbury, realizing plastic circularity means collaboration with industry partners and customers in evaluating infrastructure to better enable collecting and sorting, as well as finding opportunities to stimulate new markets for recovered materials. Open discussion and transparency are also essential elements in advancing circularity. "We need to recognize that reducing our environmental impact in a meaningful way requires careful consideration. Issues like mass balance and carbon emissions need to be debated in an open and transparent manner. We must look at proper lifecycle analyses for different types of materials," adds Kingsbury.

Evonik

FIGURE 2. Products aimed at advancing renewable energy sources, such as biogas, are major innovation areas in the CPI

Nella Baerents, global sustainability director at Kraton Corp. (Houston; www.kraton.com) also lists collaboration and transparency as two key pillars of any company's environmental strategy. "We collaborate with customers to develop lifecycle assessments to offer data about a product's overall sustainability footprint," she explains. The company aims to complete 12 such lifecycle assessments in 2020. The transparency enabled through comprehensive sustainability reporting and data management regarding product sustainability also promotes opportunities for renewable and recyclable products to substitute existing materials, she adds.

Making success measurable

To preserve environmental sustainability, the concept of sustainability itself must transition beyond an abstract concept into tangible best practices and goals. "In the past, this industry didn't really know what we were talking about when we were talking about sustainability, because it was not measurable," explains Stefan Haver, head of corporate responsibility at Evonik Industries AG (Essen, Germany; www.evonik.com). "About five years ago, Evonik integrated a facts-based approach to sustainability into our strategy process," adds Haver. Examining customer needs, regulatory requirements, exposure hazards and more, Evonik has targeted areas of its portfolio where sustainable solutions make sense for product development, including the development of mineral-based, recyclable, nonflammable insulation materials and customized hollow-fiber membranes designed for biogas separation (Figure 2). For product areas that are deemed sustainability-challenged, Evonik aims to find substitutes or alternative ways of production. "Our customers want us to help them improve their sustainability record. There is a strong market need, and this is why we must make our impacts measurable," he emphasizes. Social movements related to climate change are also putting pressure on manufacturers. "For many years, people perceived the chemicals industry as part of the environmental problem, but today, there is at least some understanding that the chemicals industry is also a part of the solution."

"Ecological, economic and social targets must be brought together to achieve clearly traceable, measurable and reproducible results. Sustainability remains an indispensable prerequisite of creating value and growth," says Martin Vollmer, chief technology officer at Clariant AG (Muttenz, Switzerland; www.clariant.

com). However, overarching sustainability goals cannot be achieved by one company alone — cooperation along the value chain is crucial for advancing circular technologies and business models, and also meeting consumer demands. "Consumers have become better informed over recent years and are increasingly demanding sustainable products and ingredients. Most players along the value chain today understand that climate protection has become indispensable for a sustainable future," says Richard Haldimann, Clariant's head of innovation excellence, citing energy and water consumption, CO_2 emissions and waste as major drivers for sustainability advancement.

With the intensified global focus on product lifecycles, sustainability considerations come into play even in the early-development phase of a product's life. At 3M (St. Paul, Minn.; www.3m.com), every new product that enters the company's commercialization process is evaluated to demonstrate its sustainability value, in terms of recyclability, energy and water savings, responsible sourcing, renewable materials and more. "By reducing the amount of raw materials and total energy required to make a product, we are improving our operational footprint while improving our portfolio," says Gayle Schueller, vice president and chief sustainability officer at 3M. "We aim to make our customers become more sustainable, including a goal to help them reduce their greenhouse gas (GHG) emissions by 250 million tons of CO_2 equivalent emissions through the use of our products," adds Schueller.

Underlining the importance of environmental considerations to business objectives, Lanxess AG (Cologne, Germany; www.lanxess.com) directly connected its finances to sustainability performance when it signed a new revolving credit line that links interest rate terms to the fulfillment of ESG (environment, social and governance) criteria. Some of the company's sustainability goals have included optimization of its portfolio toward products that are less emissions-intensive over their entire lifecycle. "A complete lifecycle approach is a key component of achieving a successful transition to a sustainable, low-carbon and circular economy. The end of a product's life can go through several cycles — the mechanical and chemical recycling of waste, as well as energy recovery," says Hubert Fink, member of the board of management at Lanxess. "To this end, we are constantly developing sustainable material solutions and also relying on the new possibilities of digitalization."

Feedstock efficiency

Shifts in feedstock sourcing are a core part of gaining ground in a circular economy. However, achieving circularity is a more nuanced endeavor than simply swapping a traditional feedstock for a renewable one. "If you only switch to renewable materials without resolving a product's recyclability, you will end up disappointing consumers, because you will never be able to make everything fully circular due to the huge losses in the recycling process," says Tom van Aken, chief executive officer of

Avantium

FIGURE 3. The search for renewable feedstock has led to the development of brand-new chemical technologies, and brought innovation to the molecular level

Avantium

FIGURE 4. Increasingly, a "design for recylcability" mindset is driven by consumer interest, such as with Avantium's PEF-based beer bottle

Avantium N.V. (Amsterdam, the Netherlands; www.avantium.com). Converging these two trends will require not only bio-based "drop-in" replacement chemicals that are identical to their petroleum-based counterparts, but also the development of brand-new materials and process technologies. "With the trend toward renewable feedstocks, different types of monomers will be coming onto the market," adds Van Aken.

Avantium has developed several new technology platforms based around sugar feedstocks, bringing together drop-in replacements for commodity chemicals and novel molecules to yield new resins. The company is currently working on a 5,000-ton/yr demonstration facility for its catalytic process to produce furandicarboxylic acid (FDCA) from plant-based sugars. Avantium intends to combine the FDCA monomer with renewable monoethylene glycol (MEG), for which the company opened a demonstration plant last year (Figure 3), to yield the polyester resin polyethylene furanoate (PEF). "PEF can be made completely from plant-based materials, but is also fully recyclable," says Van Aken. "We can start moving toward renewable feedstocks and stop relying on fossil feedstocks, and in parallel switch to circular products," he continues. He observes that consumers are currently the strongest driving force, more so than industries or governments, to promote circular economy goals. "I think the quickest transition will be driven by consumers. Consumer demand will steer the supply chain in a more renewable, circular direction, and that will accelerate the transition."

Last year, Avantium and beverage manufacturer Carlsberg debuted a beer bottle made of PEF and paper (Figure 4), and additional PEF packaging applications are expected to launch soon. "We have high expectations for how consumers and brands will respond to a sustainable circular product like the paper bottle," adds Van Aken. Avantium is also beginning to look at manufacturing chemicals using CO_2 as a feedstock, and also integrating electrolysis processes alongside catalytic platforms. "We are realistic that this will take years to optimize and scale. I absolutely believe that in the coming ten to fifteen years, these are the types of technologies we will see coming onto the market. People will be building electrolyzers and using CO_2 as feedstock," he explains.

In this same vein, Evonik has worked with Siemens AG (Munich, Germany; www.siemens.com) on the Rheticus project, which is piloting the manufacture of hexanol and butanol from CO_2. "For this kind of circularity, you can no longer find solutions in isolation, but rather in close relationships with other businesses with different competencies. We will also see a deeper integration of the chemicals industry into the business of our customers,"

says Evonik's Stefan Haver.

Like CO_2, finding use for other waste streams is also instrumental in the circular economy. For instance, Clariant's sunliquid process utilizes agricultural residues, such as wheat or corn straw, to produce bio-based products, including biofuels. "Further long-term sustainability goals include the use of CO_2 as a raw material, and we are also developing catalysts for Power-to-X technologies, such as producing methanol from CO_2," adds Clariant's Martin Vollmer.

Manufacturers of products like catalysts and batteries, which use expensive and scarce raw materials, are faced with some unique circular economy challenges. The supply chains for these materials are complex and, in some cases, can potentially be entangled in international conflicts and unsavory practices — particularly the elements that are used in battery cathode materials.

"The use of precious metals, such as platinum and palladium, cannot be avoided for certain classes of products, but we have considerable expertise in designing and developing products that minimize the amounts of precious metals needed while still delivering expected performance," says Philip Blakeman, sustainability director at Johnson Matthey (JM; London; www.matthey.com). "We are also experienced in recycling these metals once products have reached the end of their useful life."

For these types of materials, sustainability challenges stretch across all parts of the supply chain, and widespread collaboration and transparency are becoming increasingly critical. "Focus on ensuring the whole supply chain is operating ethically toward people and the wider environment will continue. Upstream companies are increasingly looking for ways to source responsibly," explains Blakeman. Furthermore, he emphasizes that manufacturing companies who take an active role in reducing GHG emissions will see better opportunities in the market, as downstream customers also try to minimize their own environmental impacts. "Investors, employees, governments and customers increasingly expect companies to execute meaningful activities to improve their environmental impacts throughout the whole supply chain and product lifecycle," he adds. "Being able to source renewable energy and implement effective carbon-capture technologies are vital for the industry to successfully meet expectations."

Globally, JM has reduced its carbon intensity per ton of product produced by 20% since 2017 and is active in developing renewable products for emerging areas, including the hydrogen economy and electric vehicles. The company has developed fuel-cell components that convert hydrogen gas into zero-emissions electricity (Figure 5), and is in the process of commercializing its eLNO ultra-high-energy-density battery cathode material, which enables lower cobalt content for electric vehicle manufacturers.

Operational and energy gains

Companies can introduce sustainability measures into manufacturing operations not only through the use of renewable materials as feedstock, but also through various tactics to improve operational efficiency. "We work to increase resource efficiency by decreasing our plants' energy use, switching to cleaner-burning fuels, improving spill and leak prevention, enhancing wastewater treatment and increasing production consistency," says Kraton's Baerents. As an example, she highlights the company's manufacturing plant in Sandarne, Sweden, which has developed a mixture of purified pitch oil to power the facility's heaters. This oil is obtained as a byproduct from the site's distillation unit for bio-based crude tail oil. "This sustainable fuel powers normal operations, and fossil fuels are only used to start up and shut down the process," explains Baerents. "This improvement reduced the use of fossil fuels and increased our resource efficiency by allowing the steam boilers and heaters to run with our operations' byproducts," she adds. Globally, the company is targeting a 25% reduction in GHG emissions intensity by 2030.

As a cornerstone of corporate sustainability plans, many chemical companies are seeking out renewable energy sources to power their operations. "For instance, we now utilize landfill-gas boiler fuel as a replacement for natural gas," says Cassidy Carlile, director of environment and sustainability for the chemical division of Milliken & Company (Spartanburg, S.C.; www.milliken.com). The company has also installed solar panels at its corporate

Johnson Matthey

FIGURE 5. Advanced fuel-cell components are enabling the production of zero-emission electricity from hydrogen

headquarters as a measure to reduce environmental footprint. "Additionally, Milliken is currently installing a combined heat and power system to supply power and steam to two of our largest plants. This project will further reduce our GHG emissions," adds Carlile.

Alongside renewable energy, Carlile also sees an increased focus on product lifecycle considerations and waste reduction, pointing out that over 90% of Milliken's manufacturing locations operate with zero waste sent to landfills. Along with a tenfold increase in renewable energy use, among the company's sustainability goals are plans for a 25% reduction in GHG emissions, water usage and solid waste by 2025.

3M has improved upon its own GHG emissions through the use of renewable electricity — the company has installed multiple solar arrays to power its manufacturing sites in Corona, Calif. (Figure 6) and Tuas, Singapore. In Singapore, 3M has created one of the country's largest solar farms. Moving forward, 3M has set its sights on 100% renewable electricity usage by its global operations by 2050, with an interim goal of 50% by 2025.

To halve its GHG emissions between 2004 and 2018, Lanxess focused not only on reducing CO_2 emissions, but also on nitrous oxide (N_2O) by constructing a N_2O-reduction plant at the Chempark in Krefeld-Uerdingen, Germany. According to the company, this plant reduces emissions of CO_2 equivalents by about 1.5 million metric tons per year (m.t./yr). Furthermore, as part of its over-arching approach to become climate-neutral by 2040, the company is building another N_2O-reduction plant in Antwerp, Belgium, which will start up in 2020 and will reduce CO_2 equivalents emissions by some 150,000 m.t./yr.

Also in Antwerp, Lanxess is part of a shared steam network, which started up in 2019. "The steam network in Antwerp is used in conjunction with other chemicals companies. The system helps reduce energy costs, and is expected to reduce CO_2 emissions by about 10,000 m.t./yr for Lanxess. Reductions will likely be 100,000 m.t./yr across all participating companies," says Hubert Fink, member of the board of management of Lanxess. At its site in Porto Feliz, Brazil, Lanxess operates a biomass-powered cogeneration plant for the production of electricity and steam. "Thanks to the use of biomass raw materials, energy can be produced on a CO_2-neutral basis," emphasizes Fink. The company is also in the process of switching to renewable energy sources at its sites in India. "In India, we are massively expanding the supply of biomass and solar power, and will no longer use coal or gas," adds Fink. With these projects and other measures, Lanxess plans to decrease its CO_2 emissions by a total of 800,000 m.t. by 2025, investing up to €100 million in the process.

On the operational side, Braskem America (Philadelphia, Pa.; www.braskem.com/usa) has installed automated monitoring systems for cooling-tower treatment chemicals, reducing the amount of blowdown to the sewer systems — this change has saved over 83 million gal/yr of water since 2013, says Geoffrey Inch, circular economy and sustainability director, Braskem North America. Another notable project that is currently underway at Braskem's Marcus Hook, Pa. location addresses hydrocarbon losses to flare from vent-recovery compressors. "After analyzing the losses, it was determined that through the modifications implemented in this project, there is potential to reduce up to 10 million pounds of hydrocarbon losses to flare each year," explains Inch. This project is expected to be completed in mid-2020. Other sustainability-focused projects underway at Braskem seek to reduce monomer losses, control water usage, minimize additive consumption and find renewable pathways for new products. Braskem currently offers bio-based versions of polyethylene and ethylene vinyl acetate, and the company is working on a demonstration plant with Haldor Topsoe A/S (Lyngby, Denmark; www.topsoe.com) to manufacture renewable MEG.

A keen focus on waste reduction has been the driving force behind several larger-scale projects at Huntsman. "At our methylene diphenyl diisocyanate (MDI) production facility in Shanghai, China, we built a new plant to chemically recycle a high-volume byproduct — anhydrous hydrogen chloride — to produce chlorine, which is re-used as a raw material for new MDI production," explains Huntsman's Gerrard. Also, at the company's site in Conroe, Tex., an evaluation of equipment washdown procedures revealed an opportunity to isolate the hazardous cyclohexane within a process waste stream and recover this material for commercial sale. "After this change, the Conroe plant went from producing 3.7 million pounds of hazardous waste to zero," adds Gerrard.

Practical progress

The steps being taken to improve sustainability performance in the CPI range from small housekeeping tasks to large-scale capital projects to the development of brand-new chemical technologies. For Huntsman, some of the smaller-scale initiatives have included recovering and re-using pallets, treating and re-using intermediate bulk containers (IBCs) in shipping and converting from diesel-powered to electric forklifts. At Huntsman's Deggendorf, Germany site, production storage tanks were equipped with new insulated housing, which considerably reduced natural gas consumption. In addition, the company has begun rainwater-recovery activities to improve water usage at sites in India, Indonesia and Italy.

Corporate sustainability measures are certainly not limited to operational improvements. At Braskem, updating lighting systems to LED

equipment and offering recycling receptacles have served to reduce the company's environmental footprint. Drilling even deeper into sustainable practices at all levels of the enterprise, Braskem began monitoring its GHG emissions per Scope 3 of the Greenhouse Gas Protocol's (www.ghgprotocol.org) Corporate Value Chain Standard. "Areas measured in Scope 3 include business travel, downstream and upstream transportation and distribution, use of sold products, team member commutes and so on. Many organizations don't yet monitor Scope 3 items," notes Inch. Overall, Braskem has set a goal to reduce its carbon footprint to 0.6 kg/ton of product produced.

One particular focus area for PPG (Pittsburgh, Pa.; www.ppg.com) is reducing spills and releases. "One of our key sustainability milestones in 2018 was a 28% improvement in spill and release rate, with our overall goal being to achieve at least a 65% improvement by 2025," explains Tim Knavish, PPG executive vice president. Intensively tackling spills and releases not only improves resource efficiency, but also reduces costs and hazards associated with waste disposal and environmental cleanup. "We work first toward absolute material utilization throughout our manufacturing processes followed by eliminating, minimizing, reusing and recycling the waste we do produce," says Knavish. To meet waste-reduction goals, PPG has initiated spill-prevention procedures that require operators to walk along production lines prior to liquid transfer, visually checking for any potential spill risks, such as open drain valves or pumps feeding into already full tanks. Although much of PPG's water consumption is for equipment cleaning rather than for production, Knavish notes that the company still takes advantage of opportunities to optimize water use in all facilities. "We are improving our processes to require less cleaning and are working toward a 20% reduction in water intensity by 2025," he adds. At PPG's manufacturing facility in Huntsville, Ala., a project that switched an emissions-filtering unit from an open-loop to a closed-loop design has reduced water use by 4.6 million gal/yr.

The plastics problem

An undeniable area of concern for chemical manufacturers is mitigating waste — particularly, the accumulation of plastic waste. One way that manufacturers are improving their environmental footprint is through efforts to reduce waste from their own operations, including plastic pellets and powders, which have many detrimental effects when released. The Operation Clean Sweep (OCS; www.opcleansweep.org) program provides guidelines to help companies prevent plastic pellets, flakes and powders from entering marine ecosystems. "Since our founding, we have been a member of OCS, with established practices in our plants to make sure that pellets are fully contained and do not leave the site," says Jim Becker, vice president of polymers and sustainability at Chevron Philips Chemical Co. (CP Chem; The Woodlands, Tex.; www.cpchem.com). Obviously, handling plastic waste also goes beyond a plant's boundaries, and global recycling efforts must be bolstered to handle the accumulation of post-consumer plastics. "In many countries, the infrastructure for waste collection and management is missing. One of the things we're going to see over the next five years is a great deal of investment and work on developing that infrastructure," says Becker. He believes that chemical recycling — treating plastics to break them back into their constituent molecules — will be a key part of tackling plastics waste worldwide: "Chemical recycling is a very circular solution. It turns plastic waste into a feedstock for virgin resins," he adds.

He mentions a project in India where the Alliance to End Plastic Waste is working to set up small chemical-recycling units along tributaries of the Ganges River with the vision that people will deposit their plastic waste to the units, which will in turn generate fuel. "This creates an economic incentive for people to recycle their waste rather than leave

3M

FIGURE 6. The share of renewable energy powering CPI manufacturing plants is set to skyrocket in the coming years, as companies begin to execute their longterm sustainability goals

it unmanaged," emphasizes Becker.

CP Chem is in the early phases of development on a variety of chemical-recycling projects, including its combination with existing mechanical recycling techniques to greatly expand the breadth of materials that can be efficiently handled. "The combination of chemical and mechanical recycling is going to be a bigger part of the picture over the next 3–5 years. It is difficult to mechanically recycle everything, and there can be barriers to convert mechanically recycled resins back into useful products," says Becker. For instance, mechanical recycling usually requires finely separated waste streams, whereas chemical recycling processes are suited to handle mixed streams. Also, chemical recycling opens the door for recycling multilayer packaging, and other traditionally challenging materials like polystyrene.

CP Chem's American Styrenics joint venture with Trinseo produces circular polystyrene through a chemical recycling process, but Becker notes that there is still much work to be done to scale chemical recycling to handle massive amounts of unmanaged plastic waste. "We have to get the whole supply chain working properly. There will be many innovations in order to make chemical recycling viable and the industry is working on efficiencies, catalyst technologies and other improvements," he continues.

Clariant is also working with partners in the field of chemical recycling to secure future access to reclaimed raw materials, such as ethylene and propylene, and working toward tackling some of the challenges associated with the utilization of post-consumer and post-industrial recycled (PCR/PIR) materials. "Among our longer-term sustainability projects, we are investigating the chemical recycling or upcycling of plastic waste from either clean-grade or mixed material streams for reuse in new virgin-quality plastics for fuels. A special focus within this work is on fundamental absorption mechanisms for removing harmful impurities," says Clariant's Haldimann.

Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) has launched two chemical recycling technologies — one focused on polyester and the other tackling mixed plastics streams. The company's Polyester Renewal Technology (PRT) reclaims waste polyesters from landfill and recycles them via glycolysis or methanolysis, reducing the polyesters to monomers, which are then fed back into the polyester manufacturing process. Eastman expects to begin operation of a commercial PRT unit in the next 2–3 years.

To implement the mixed-plastics-recycling process, which began commercial operation in 2019, Eastman modified the front end of a cellulosics production unit to handle mixed-plastic feedstock. The process partially oxidizes the plastic and efficiently converts it into basic building blocks for other chemicals. In 2020, the company anticipates processing up to 50 million pounds of waste-plastic feedstock. "Our advanced circular recycling technologies give us an opportunity to develop partnerships across the value chain to provide solutions, including better end-of-life options that will have an impact on the global waste problem. It's extremely important that we succeed here, as we can help pave the way for the entire industry to make a material difference for a global issue," emphasizes Steve Crawford, chief technology and sustainability officer at Eastman. "We see chemical recycling as a vital complement to mechanical recycling. Chemical recycling can now properly deal with the more complex plastics that mechanical recycling was not designed to process. We are focused on the vast amount of materials that are not suitable for basic recycling," adds Crawford.

Other efforts to curb plastic waste include designing end products themselves to be intrinsically more recyclable. According to Becker, CP Chem is working with its customers to re-design packaging structures with recyclability in mind, and also to incorporate more post-consumer recycled materials. "There's a lot of work going on in packaging design, because the industry as a whole needs to have packaging that is more easily recycled. We're going to see more of that in the coming years. We are certainly seeing consumer preference drive sustainable product development, but this is also reflected from a regulatory standpoint," Becker concludes.

One part of Clariant's plastics strategy has taken the form of dedicated additives that are intended to improve the compatibility of plastics in current and future recycling processes. "The development of customer-tailored additives will enable brand owners to significantly increase the share of recycled material in the packaging of their products," explains Haldimann. "We must put an end to the throw-away mentality, and a stronger circular economy with recycled plastics will help accomplish this change. We see an enormous innovation potential in appropriate end-of-life product strategies," he adds.

Milliken has also developed performance-modifying chemicals that allow for recycled polypropylene to be better utilized in end products without sacrificing physical properties. "We are analyzing new products using lifecycle analysis principles. Our sustainability efforts include convening scientists and thought leaders to take action on solving plastics' end-of-life challenges," says Cassidy Carlile of Milliken. Looking ahead, this type of collaboration — between industry, academia and regulatory bodies — will surely be an instrumental element to accelerate circularity in the CPI. ■

Mary Page Bailey

Part 1

Updating Legacy Rotating Equipment

A brief look at the benefits of installing modern materials and design upgrades through retrofit projects in chemical plants

Pharic Smith
Sulzer Pumps (UK)

IN BRIEF

Modern chemical manufacturing plants depend on the reliable operation of numerous important assets to maintain productivity. Retaining legacy equipment is a cost-effective way to minimize capital expenditure, provided efficiency and reliability can be upheld. The implementation of retrofit projects allows modern materials and parts manufacturing techniques to update existing components extending the asset's service life.

FIGURE 1. Spare compressor rotors can be exchanged quickly to minimize downtime

In many cases rotating equipment, such as steam turbines, generators, pumps, compressors and expanders, make up an important part of the production process. Through continued use, components wear and clearances increase, leading to reduced efficiency. At the same time, processes change and greater productivity may be expected from the legacy equipment. Tackling these challenges successfully can reduce operating costs and improve reliability.

Optimizing uptime

The chemical manufacturing sector offers many challenges, not least of which is the operational environment — working with corrosive materials as well as steam can increase the pressure on the maintenance team. Working with equipment that has been in service for many years, especially when there is no support available from the original equipment manufacturer (OEM), means alternative solutions have to be found when repairs and upgrades are required.

Tight production schedules mean that downtime has to be minimized, so using a planned maintenance program is always preferred to prevent unexpected failures that can cause lost revenue. While on-site maintenance teams are often well-versed in the operation of the equipment — expert support can reduce repair times and deliver cost-effective solutions for more complex repairs.

To maximize the original investment in equipment, the service life needs to be extended as far as economically possible. Retrofit projects offer the opportunity to upgrade or replace components that can increase performance through improved design or materials.

Cost-effective solutions

Large-scale pumps are often cited for retrofit projects because a life of continuous operation can lead to wear of the impellers/rotors, which reduces efficiency and increases running costs. Those operating in the chemical manufacturing industry may have to endure a challenging working environment.

For example, nitric acid, which is an essential raw material for the manufacture of fertilizer, is created using inexpensive com-

ponents: ammonia, water and atmospheric air. However, the manufacturing process is very energy- and capital-intensive, using several turbomachines, such as compressors, pumps, tailgas-expansion turbines and several large motors. It is, therefore, important for manufacturers to maintain a high level of efficiency for the process to remain profitable.

Rather than replacing complete assets when their productivity starts to drop, it is far more cost-effective to repair the worn component and even improve its design at the same time. Modern three-dimensional (3D) laser-scanning technology means that the original OEM drawings are not required; parts can be created from the original component, even if it has been damaged.

Boiler feed pumps

Many manufacturing plants use steam to generate their own electricity supply, and these systems rely on boiler feed pumps to deliver a consistent water supply. In many cases, these important assets can perform reliably for decades, but reduced efficiency will take its toll on the cost of operation. However, after so many years, the OEM may not be in a position to supply new parts, so an alternative solution is needed.

Today, seal improvements and efficiency upgrades through nonmetallic wear parts and improved rotor designs can be created and manufactured using state-of-the-art equipment. Modern design processes and additive manufacturing techniques can greatly reduce the lead time for new parts.

Retrofit programs can go much further and alter the output of the asset where demand from the pump has changed over the years. By changing impeller profiles or reducing the number of stages, the pump can be optimized for its current application, often reducing the power requirements and reducing running costs.

Compressors

Large compressors are commonplace in the chemical manufacturing sector and they often operate around the clock. As such, reliability and efficiency are very important, so rigorous maintenance schedules and condition monitoring equipment are usually in place.

In many cases, compressor operators hold spare rotors that can be exchanged quickly, minimizing downtime and allowing more time to refurbish the rotor that has been in service (Figure 1). However, this procedure does not enable time to access to the stationary section of the compressor, which may also need attention during an overhaul or a retrofit project.

This can be mitigated by using laser-scanning technology and by creating a 3D computer-aided design (CAD) model of the rotor and the casing. By combining the two, and using cutting-edge technology, a performance chart for the 3D model can be generated. This can be compared to the actual data from the compressor itself and used to refine the model until it is a true representation.

Modeling improvements

From this point, designers can introduce improvements to the model and establish their influence on output and efficiency. Changes in impeller profiles, enhancements to bearings and labyrinth seals, can all be simulated and evaluated to establish the most beneficial designs.

Modern manufacturing and machining technologies can be applied to not only reduce lead times, but also create more efficient components, such as impellers with 3D

FIGURE 2. Custom manufacturing of new components can reduce lead times

FIGURE 3. Precision fit of gas turbine parts increases efficiency

FIGURE 4. Modern machine tools can reduce the lead time on new, optimized components

FIGURE 5. Steam turbine reliability can be improved through retrofit projects

vane geometry (Figure 2). These can all be used to improve performance and increase the mass flowrate if necessary.

The advantage of the theoretical 3D CAD is that the suggested improvements can be trialed and assessed for their impact on other components, such as the intercoolers. In some cases, upgrading the ancillaries can be justified for the increased output. Furthermore, the data can all be examined to enable a more informed decision.

Hot-gas expanders

With such huge amounts of energy involved in chemical manufacturing, any method of recovery needs to be properly maintained to maximize its benefit. The operational environment of hot-gas expanders means that they are subject to challenging conditions with considerable stresses put on the rotor and its bearings.

Rotating at speeds up to 11,000 rpm, the rotor needs to be supported by bearings that can withstand the operational stresses and provide long-term reliability. A retrofit project can upgrade the cylindrical sleeve bearings to tilt pad components. Spherical seated bearings can be replaced with a design using cylindrical rollers, offering better long-term performance.

The rotor itself has a multi-stage design where a hollow shaft with internal cooling passages holds the turbine disks and blades in position with a single thru-bolt. This bolt is subjected to considerable thermal stress and is often machined from stainless steel in the original build specification.

The part can be upgraded to 450 stainless steel alloy that allows increased bolt stretch and greater bundle crush on the rotor assembly. The dimensions are machined to exactly match the original using the 3D CAD drawings and can be installed as part of a rotor refurbishment.

Improved blade performance

Hot-gas expanders can also benefit from a reduction in blade tip leakage, which accounts for substantial losses in efficiency in legacy equipment. Installing an abradable coating on the stator inner surface provides improved clearance control for the rotor blades. Clearly this sort of upgrade requires the expander to be under maintenance for an extended period, so is best suited to a planned shutdown period.

Further improvements can be achieved by upgrading the materials used to manufacture the blades themselves. In applications requiring high strength and good corrosion resistance up to 1,300°F (700°C), the use of a super alloy, such as A286, in the blades can be beneficial.

Of course, with turbine blades operating in high-temperature environments, gas turbines have several characteristics in common with gas expanders, and as such, similar technologies can be applied to both. Developments in blade coatings can reduce fouling and oxidation in both the rotating and stationary sections.

Gas turbines

Important pieces of equipment, such as gas turbines (Figure 3) can provide both primary and back-up power supplies, so their reliability is paramount. Over time, design improvements have been developed both by the OEMs and independent maintenance providers and these can be applied to the installed equipment through retrofit projects.

For example, in the Siemens V-Series gas turbines, the flame tube F-ring has a tendency to oxidize and produce scale that can be ingested by the turbine during normal operating conditions. To improve this situation, the component can be machined to expose fresh material and allow an Inconel overlay to be welded to the new surface before being machined back to the required diameter. Inconel 82 is a nickel chromium alloy with high strength and an outstanding corrosion resistance that will improve the durability of the component.

Similarly, the combustion section of the gas turbine can be protected with a thermal barrier coating (TBC) applied to all of the flame tubes and other hot-gas-path components. A ceramic TBC applied to the bezel rings and segment plates, mixing elbows and inner casing, increases the resistance to thermal distress in the hottest areas of the unit.

Other improvements can be made to the cooling performance of certain parts, such as the flame tube, to increase durability of the parts by reducing oxidation and erosion. Together, all of these improvements can extend reliability and ensure continued efficiency of the gas turbine.

Meeting new standards

As legacy equipment continues to deliver reliable service, modern stan-

dards evolve for the benefit of the environment and the improvement of operation and efficiency. Many of these standards can be applied retrospectively, and it is often quicker and more cost-effective to modify existing machinery, rather than replacing it with new equipment.

Understanding what can be achieved by a retrofit project, and how best to apply it, are important skills that are gained through experience in both the industry in question and in developing state-of-the-art solutions. By developing theoretical models and fine-tuning the design, engineers can highlight the benefits and ensure that the equipment is suitable for refurbishment.

The ability to improve efficiency and reduce energy consumption through modern engineering also offers the opportunity to reduce the environmental footprint of the business. As more pressure is placed on industrial plants to improve the environmental impact of their operations, retrofit project have the potential to deliver both a cost and CO_2 emission reduction.

Reaping the benefits

Every piece of plant equipment presents its own challenges, but it is possible to address many of them by working with experienced engineers who understand the demands of the process, as well as the design of the equipment involved. Using a well-defined and integrated upgrade program can deliver significant improvements to the expected service life of the equipment as well as improve productivity.

Retrofit projects represent an opportunity for the cost-effective and efficient introduction of new components that use modern materials and manufacturing techniques (Figure 4). The ability to create one-off parts quickly, without OEM drawings, minimizes downtime and ensures a successful turnaround during a planned outage.

By making significant improvements in efficiency and reliability, chemical plants can reduce their CO_2 emissions by making better use of the energy from waste gases, which in turn reduces the amount of energy that is required from steam-powered generators. Independent service providers can offer expertise in reducing losses, improving turbine performance (Figure 5) and upgrading rotating equipment, enabling chemical manufacturers to see enhanced performance and improved lifecycle costs. ■

Edited by Gerald Ondrey

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Determining Overall Pump Lifecycle Costs

Beyond the purchase price, there are other optimizable costs that will help moderate pump-related expenses, when estimating pump lifecycle costs

Geoff VanLeeuwen
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IN BRIEF

Facility managers who rely on industrial pumps for the various liquid-transfer duties in their manufacturing processes may occasionally think that once the pump has been purchased, the majority of the heavy lifting has been completed. It is easy to see why this mindset might become prevalent. After all, identifying the right pump for the right process requires a lot of time and due diligence, from performance reviews to cost estimates, to even soliciting opinions from other manufacturers.

FIGURE 1. Pump installation cost is an area that is ripe for improved optimization, especially in new installations

In reality, studies of different types of manufacturing operations have indicated that, when all is said and done, the purchase price of a pump will only be 10 to 15% of its total lifecycle cost — with "lifecycle cost" defined by The Hydraulic Institute (www.pumps.org) as the "total lifetime cost to purchase, install, operate, maintain and dispose of the pump."

Based on that definition, the reality is that cutting a check for the purchase price of the pump is only the first of many potential expenses that will be incurred over the pump's operational lifetime, which — if the operator is fortunate — can be as long as 20 years or more. Hand in hand with that, pumps are said to account for between 20 and 25% of the energy usage in a manufacturing operation. Therefore, it is imperative that facility operators analyze their pre-buy research not only from an initial-cost perspective, but also from a total lifecycle cost viewpoint.

To do that, there are five cost factors to consider when attempting to arrive at a trustworthy figure for what a pump's total lifecycle cost may be:

1. Capital costs
2. Installation costs (Figure 1)
3. Operating costs
4. Maintenance costs
5. Decommissioning costs

Let's take a closer look at all five.

Capital cost

As mentioned, capital expenditure (capex) is the amount of money paid to actually purchase the pump, and is the first and most obvious lifecycle cost. But identifying and optimizing that capex cost involves much more than comparing and contrasting price tags.

The first consideration should be identi-

fying the pumping technology that best suits the needs of your liquid-transfer processes. Usually, this comes down to a choice between positive displacement (PD) and centrifugal-style pumps (Figure 2), with the type of technology that is ultimately chosen having huge implications for the total lifecycle cost of the pump.

In many instances, final pump selection can come down to an either/or choice:

- If a PD pump is chosen, will its operation require the use of a gear reducer or speed-reduction device? If it will, that is an added upfront cost that must be considered, since centrifugal pumps do not need speed reducers
- There have been a number of significant advances recently in the development of leak-free or seal-less pumps. These types of pumps, however, are generally more expensive than sealed pumps, but on the other hand, an inventory of replacement seals will not need to be purchased, stocked and tracked
- Within the PD realm, air-operated double-diaphragm (AODD) pumps are a unique technology in that they do not need a traditional electric or fuel-powered motor to operate and have no couplings or seals that need to be maintained or replaced (Figure 3). The only daily operational cost is paying for a supply of air, but this means that the facility must be able to accommodate that capability. AODD pumps also do have a number of wear parts that will need to be monitored, including their diaphragms, balls and valve seats

Particular to the chemical process industries (CPI), over the years centrifugal pumps have become the default liquid-transfer technology in many of the world's chemical-processing systems. Because of this, many chemical processors will always choose a centrifugal pump because they know how they operate, are familiar with their benefits and are confident they will get the job done.

The problem with this mindset is that it means that many chemical-processing systems have been designed around the needs of the pump, rather than the needs of the system. For example, design engineers will design their systems so that raw materials can be blended or heated in a way that their viscosity is brought to a level that enables them to be handled by a centrifugal pump. In this case, they are reconditioning the material to fit the need of the pump, regardless of any potential lifecycle cost impact.

The operator, in addition to getting the viscosity to a centrifugal-friendly level, must also ensure that the pump continues to operate at its best efficiency point (BEP), generally believed to be a window in which the pump operates at 80 to 110% efficiency levels. Any time spent operating outside the BEP can result in shaft deflection that will place higher loads on the pump's bearings and mechanical seal, which can damage the pump's casing, impeller and back plate. This domino effect will lead to higher maintenance and part-replacement costs that — teamed with the costs required to actually keep the pump operating at its BEP — will increase total lifecycle costs.

FIGURE 2. Designed to be economical and simple, centrifugal pumps occupy more than 75% of the global pump market and are often considered as a default liquid-transfer technology in many CPI systems

Installation costs

Determining installation costs and their eventual effect on total lifecycle expenses requires a complete overview of the pumping operation. Some questions to consider include the following:

- Will any modification to the pumping system be needed when the new pump is introduced or can it just be plugged into the existing infrastructure?
- Will new or modified connections to the process piping, electrical wiring and instrumentation, and auxiliary systems and utilities be needed?
- Are there any special weight considerations that could lead to the need for a special foundational platform, for instance, a baseplate?
- Will any boring into the existing foundation, or the pouring of a new foundation, be required?

This last question is the one that can have the biggest effect on total lifecycle costs. Some pump technologies are easy to install; for instance, AODD pumps need only air and discharge hose connections to do their jobs, even if that job demands that the pump operate underwater (Figure 3).

Vertical pumps, on the other hand, are typically less expensive than some other styles, but they sometimes need extensive foundation work that could require boring as much as 30 ft (10 m) into the ground just to install the pump. This can prompt the facility operator to employ some comparative if/then thinking: "If I want to use a more economical vertical pump, then it will cost quite a bit in installation costs." By taking that into consideration and reviewing

FIGURE 3. Some pump technologies are easy to install. For instance, AODD pumps need only an air and discharge hose connection to be hooked to them before they are asked to do their jobs

all of the possible alternatives, that if/then statement can be turned into: "If I use a more expensive multi-phase pump, then I will have lower installation costs."

Another area of consideration during pump installation is alignment. Simply put, pumps that are not aligned properly with the motor — and many often aren't — can lead to quicker part wear that can result in inefficient operation and pump failure. There are now some pump technologies that can be pre-aligned, as they are manufactured through the use of an adapter, which eliminates the need to align the pump on-site, along with any costs associated with that alignment process.

A final expense within the installation-cost realm is the commissioning cost. This includes fees that must be paid to have the installation reviewed to ensure that it satisfies all of the parameters for proper installation and safe operation. Only after this review has been performed and sign-off received will the facility manager be able to flip the switch and begin operating the pump.

In the end, it all comes down to each individual facility's needs, wants and economic considerations, with all of the spokes in the installation-cost wheel playing a part in determining total lifecycle costs.

Operating costs

The most obvious cost here is acquiring the energy (generally electricity, fuel or compressed air) that is needed to power the pump. Here again, the style and operational capabilities of the pump technology play a notable role. For example, when contemplating a pump that operates via a motor that is 50 hp or lower, energy efficiency should not be a top-of-mind consideration for the operator. However, energy efficiency becomes a critical concern when the motor is 100 hp or larger, especially when those heavy-duty motors are featured on pumps that perform continuous-duty pumping operations.

Again, a comparison between PD and centrifugal-style pumps is in order, as follows:

- Typically, a PD pump motor is sized according to the bypass valve set point. This optimizes the motor sizing so that it is close to the actual operating points and limits the energy consumed while still enabling it to achieve desired flowrates regardless of temperature, pressure or viscosity changes during the pumping process
- Centrifugal pumps, on the other hand, are often not protected with bypass valves. Instead, centrifugal pump motors are sized according to the runout power. This essentially oversizes the motor "just in case" the pump operates at runout. In reality, most centrifugal pumps don't operate at runout, meaning that the cost for a larger motor is often a needless expense

Another cost to focus on when considering lifecycle operating expenses is the cost of any ancillary liquids needed to heat, cool or lubricate the pump during its operation. For instance, sealed pumps can require a water "quench," a process in which tap water is injected into the seal gland as a way to cool and clean the seal faces. This water is usually introduced into the pump at very low volumes, sometimes even lower than a dripping water faucet, but if 10 pumps require this treatment and they operate for 8,000 h/yr each, the costs for that water can quickly escalate. This expense is not needed with seal-less pumps.

Operating costs also contain a human element in the form of labor costs. These costs can fluctuate widely depending on the complexity of the pumping system itself. A system that regularly handles hazardous or explosive materials requires closer monitoring than one that only transfers benign materials. Though there has been growth in next-generation remote Cloud-based pump-monitoring systems and equipment in recent years, most manufacturing facilities still rely on first-hand on-site observation of the pumps to determine if they are meeting the parameters of any and all required performance indicators.

Maintenance costs

Unanticipated downtime and lost production play a huge role in the pump's total lifecycle cost. In other words, a pump that is down for maintenance is not moving liquid, which means the line is not producing product (Figure

4). While all maintenance is bound to take the pump out of service for some period of time, there are some pump technologies, such as sliding vane, that allow simple maintenance duties to be performed without having to remove the pump from the line. This will shorten the amount of time that the pump needs to be out of service. All of these things make it imperative to understand a pump's anticipated maintenance needs before it is purchased.

The ultimate impact of maintenance costs is usually tied to the number of wear parts that the pump possesses. Pump technologies like centrifugal, sliding vane and AODD have relatively few wear parts — things like seals, vanes, O-rings and diaphragms — that are easy to replace at low cost. These part-replacement costs usually total less than 20% of the cost of a new pump over its lifetime.

On the other hand, technologies like progressive cavity, screw and internal gear pumps can incur maintenance, repair and replacement costs that can approach or exceed 80 to 90% of the pump's capex cost. These types of pumps operate via highly precisioned machined metallic components that are expensive to produce. That's why these types of pumps are often called "throwaway" pumps; they are used until they break down and then are replaced because replacement is more economical than repair.

Another component of maintenance costs is preventative maintenance. This is critical if the operator hopes to reduce or eliminate unanticipated downtime in any pumping processes. Because each pump application is unique, pumps can seem fickle at times. While the operator can determine a desired target life for the pump, the reality is that, if left unchecked, unexpected failures will cause costly pump downtime.

A preventative-maintenance plan can combat this — if the plan is properly considered and makes use of the past operational history of similar pumps used in similar applications. Making well-considered assumptions regarding pump maintenance based on past history can go a long way in building a maintenance plan that can anticipate and mitigate any problems before they occur. This is another area where the recent advances in remote monitoring and data storage of a pump's operational history can help ease the burden on preventative maintenance. Some manufacturers are now offering phone applications (apps) to help track, monitor, operate and keep notes on the maintenance needs of their installed assets.

One final maintenance-related consideration for the operator is to determine whether or not it would be economically wise to purchase a spare pump that can be inserted into the pumping system on an as-

FIGURE 4. Pump reliability directly influences whether a pumping system can meet operational demands. This lifecycle expense can usually be predicted reliably by tracking maintenance expenditures

needed basis. Determining the necessity of this capex expense will also play into the calculations for total lifecycle costs.

Decommissioning costs

The final cost in a pump's lifetime is its decommissioning cost, or the cost to remove it from operation and dispose of it. While these costs are typically not prohibitive, if the pump has been used in the handling of hazardous, toxic, radioactive or any other materials that require environmental sensitivity, the costs to decommission it will be higher. When disposing of pumps that have handled hazardous materials, the number and type of regulatory requirements that must be satisfied will also play a role in determining the decommissioning costs and their ultimate effect on total lifecycle costs.

What have we learned?

When any type of list like this is created, an expected question might be: "So, which of these costs is most important if you want to optimize total lifecycle cost?" Let's look at them from least to most significant.

The one category that generally has a fixed cost that is least open to fluctuation or interpretation is decommissioning costs. Many operators may not even consider those costs as part of the total lifecycle cost package.

After that, we've found that capex and operational costs (as they relate to energy usage and pump efficiency) are not seen as a make-or-break proposition for the pump user. While it's popular to market industrial operations as "green" or environmentally friendly, the truth is that no one makes a purchasing decision based on the pump's efficiency — and there really is no compelling reason to do so because the economics of operational efficiency don't really matter for pumps that have motors smaller than 100 hp, and that's where most industrial pumps operate.

Maintenance costs are important because pump reliability is a key component in ensuring that the pumping system meets the demands of the operation. However, the costs of maintenance are usually built into operating budgets through the purchase of spare inventory or the performance of prescheduled maintenance routines, making this a lifecycle expense that can usually be predicted pretty reliably.

That leaves installation cost, which may be the least understood of all of the categories. This also means that it offers the best opportunity for improvement. Most operators ignore or care little about installation costs, viewing them as nothing more than the "cost of doing business." However, this is an area that is ripe for improved optimization, especially in new installations. Many operators can fall into the trap of relying too heavily on what has been done previously on-site or what has been done in other company facilities, without truly realizing how unique each individual installation really is.

This can lead to a situation where it is hard to know what the true costs of the installation are and their ramifications regarding total lifecycle cost. These installation costs include not only foundation work, piping and so on, but also any auxiliary systems that will need to be made part of the pumping operation. These can include priming, liquid conditioning, heating, closed-cooling, filtration, vacuum and pigging systems, some of which can be exorbitantly expensive to install.

Conversely, rather than considering the need and cost of auxiliary systems, some operators will fall back on the mindset that all problems can be solved through the incorporation of a control valve or variable-frequency drive (VFD). Control valves are useful to modulate the level of pressure that is needed to get the pump working properly — another example of building the system around the pump — but a more economical solution can be buying a pump that can inherently produce the application's required pumping pressure.

VFDs have become more affordable over the years, so some operators have begun to think that they can be a silver-bullet solution to everything that ails pump operation. While VFDs do offer a lot of functionality and flexibility and can make the system very nimble, they can wreak havoc on motors by introducing electronic pulses that will compromise the performance and reliability of the motor and other downstream pump components. Further, speed control itself is not a fix-all solution. A VFD will not help if a system's operating range is outside a pump's performance envelope.

Where do we go from here?

People in the process industries are knowledgeable, but because of the demands of their jobs they need a path of least resistance that accommodates the time, resource and production constraints that are placed on today's plant operators. The simple fact is that somehow, someway today's industry expects to achieve more output with less resources, which includes actually knowing all of the intricacies of an effectively functioning process system.

This has led more and more facility managers to turn to third-party engineering, procurement and construction (EPC) contractors for assistance. EPCs are tasked with all design, procurement and construction tasks while ensuring that the entire project is completed on time and on budget. The use of EPCs has become more and more prevalent in recent years, to the point that hiring an EPC is now essentially considered an unavoidable first step when designing, outfitting and commissioning a manufacturing plant. And EPCs can be a valuable resource — if they have the knowledge and expertise to know the ins and outs of the operation they are building and are able to answer any questions their clients may have so they can truly meet their needs. However, some EPCs prioritize short-term guarantee periods and ignore long-term lifecycle costs. Additionally, EPCs don't pursue system optimization. Instead, they are incentivized to design and construct systems that meet only the minimum requirements that are outlined in their contracts.

As mentioned earlier, the arrival of advanced remote pump-monitoring technologies promises to be a boon in optimizing pump lifecycle costs. These new monitoring systems fill a niche in what has come to be known as the Industrial Internet of Things (IIoT). IIoT is defined as a network of physical devices, systems and platforms that use embedded communication technology to share the operational intelligence of industrial machines. It combines data technology and machine learning to bring together sensor data and machine-to-machine communication technologies. This enables the identification of operational inefficiencies sooner and more reliably, creating real-time operational transparency and significant cost savings for the operator.

FIGURE 5. By working in harmony with pump manufacturers, pump operators can identify and incorporate technologies with optimized lifecycle costs that will reflect positively on the manufacturing operation's ability to meet production demands and improve the bottom line

The driver behind remote Cloud-based pump-monitoring systems is creating the ability to gather pump-performance data and store it for future use. These systems are nothing more than augmented ways to aggregate data. The challenge is finding the best ways to use these data to observe and predict pump performance, with the goal of optimizing it as it pertains to total lifecycle cost.

Final remarks

Many pump technologies are hundreds of years old and there really hasn't been a new, significant way to move 10 gallons of water 10 feet in 10 seconds developed in a century. But there are still exciting ways to improve the total lifecycle costs. Granted, these time-strapped individuals do their best to create and operate manufacturing processes that meet the demands of strict and oftentimes unforgiving production schedules. That being said, by working in harmony with pump manufacturers who are constantly looking to improve the effectiveness and reliability of their products — as evidenced by the new remote monitoring tools — they can identify and incorporate pump technologies with optimized lifecycle costs that will reflect positively on the manufacturing operation's ability to meet production demands and improve the bottom line (Figure 5). ■

Edited by Gerald Ondrey

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Batch Drying: Maximizing Product Yields

Use the strategies discussed here to maximize the yields of solid products from batch drying vessels

Eberhard Tritschler
Ekato Systems GmbH

Successfully drying a wet solid in a drying vessel does not complete the operation — the dry solids must be removed from the vessel. This step often presents challenges, because it can be difficult to fully empty drying vessels when leftover solid material remains on the interior surfaces. For batch drying processes where the residues can be dissolved into the subsequent drying run, the problem of incomplete emptying may not be particularly acute. However, for processes where the solid residues must be rinsed out of the vessel's interior prior to the next drying batch, and the rinse is lost, maximizing the yield of the dryer is of great importance. This article provides information on measures that improve and maximize the yield in batch drying processes for fine chemicals and active pharmaceutical ingredients (APIs).

Batch drying processes

In most liquid-solid-separation processes, thermal evaporation (in a vacuum contact dryer) is often the follow up step to mechanical dewatering, in order to achieve the best "dryness" result. During any drying process, all additives and solvents must be removed from the solid materials without changing the original chemical composition of the solid. In essence, there should be no changes to the molecular structure of the solids during the drying process, and no chemical derivatives should be formed due to the drying process.

A vacuum contact dryer is built to evaporate solvents from a solid by using temperature, vacuum and mechanical fluidization by agitation. The degree of residual moisture in the finished product is related to the enthalpy of the solvents, the effectiveness of the mixing and time. The degree of residual dry powders left after discharge of the vessel is strictly product related.

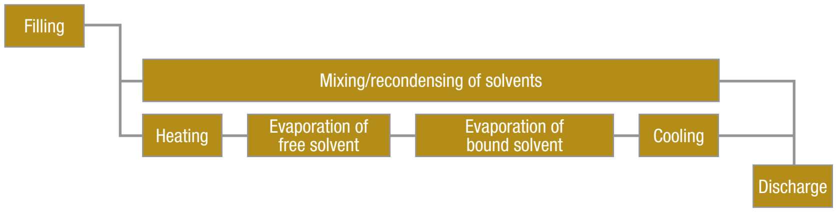


FIGURE 1. The schematic shows process steps common to many batch drying operations

Almost all batch drying processes consist of the process steps mentioned in Figure 1. Whether the steps are performed in a non-agitated tray or in an agitated vessel, the concept of evaporation and re-condensing and collecting the solvents is quite the same. When it comes to maximum yield, it is important to focus on all aspects of the drying process, not only on discharge.

Each process step has issues that require special attention. Discharge of solids is demanding — while fluids or suspensions drain well from a vertical vessel, draining a dry powder is a challenge. Residues left after draining are lost in most instances.

Maximum yield after discharge is important for the cost balance of the drying system. In a situation where a single product is processed in a vessel, leaving residues after discharge for the next drying campaign may be permissible. However, in a typical process for producing pharmaceuticals or fine chemicals, cross-contamination of different products is not allowed (Figure 2).

Vacuum dryer design

The majority of commercially available vacuum contact dryers are built with the same general features: a jacketed vessel — either horizontally or vertically oriented — with a wall-wiping agitator. Vertical (upright) solids dryers have the advantage of being aided by gravity in the natural, top-to-bottom flow of products. These dryers have the following characteristics:

- Upright cylindrical vessel with a filling-height-to-diameter ratio designed for bulk mixing
- Cone-shaped bottom to support the outflow of solids
- Jacketed to suit the selected heating system (Figure 3)
- Top-entry agitator, designed for

FIGURE 2. Residues of solid materials left on interior surfaces after drying processes can be significant

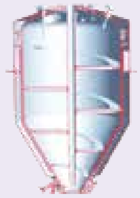
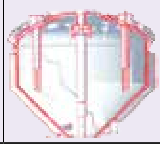
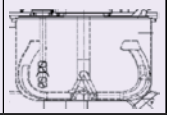
TABLE 1. DRYING VESSEL GEOMETRY SELECTION CHART					
Data			Helix	Spherical	Flat bottom
Filling volume	V_F	[L]	1,000	1,000	1,000
Inside diameter cylinder	d_1	[mm]	1,250	1,484	1,484
Cone angle	a	[deg]	21	45	0
Total surface	A_{total}	[m^2]	8.0	8.2	6.6
Surface-to-volume ratio		[m^2/m^3]	8.0	8.2	6.6
					

TABLE 2. TYPICAL IMPELLER-TO-WALL CLEARANCES			
Shape	Product	Clearance mm	Vessel design
Coarse	Coffee beans, nuts, almonds	25–50	Welded design
Grain	Crystal sugar, PP pellets	Less than 15	Welded design, special tolerances
Fine powder	Flame retardants, vitamins	Less than 15	Welded design, special tolerances and/or inside contour machined
Fine powder sticky	Active pharmaceutical ingredients, Carbon black 5–10 µm	Less than 10	Inside contour machined

solids applications (re-starting in settled solids)
- Valves and safety applications to operate as a pressure vessel

Whether the wet product is fed by gravity from the top of the vessel, or is transferred by powder transport systems, depends on the process. In both cases, the feed point/system has to be designed to avoid excessive splashing or dust formation when entering the vessel. Unguided filling might lead to accumulation of product on impeller arms or slow rotating shaft areas. Guiding vanes or funnels are recommended.

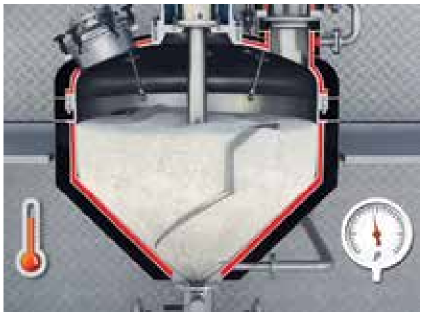


FIGURE 3. This cutaway shows surface heating

Once the solids temperature during a drying process is equal to the heating temperature, this indicates energy is no longer being used for the evaporation of solvents, so the product is effectively dry. Safety considerations might not allow the discharge of a hot solid, so cooling the product prior to discharge is mandatory. This can be achieved by changing the heating system to cooling mode.

Scaleup

Scaling up a drying process requires both small-scale testing capabili-

ties and scaleup experience. Once a product is successfully dried at a 25-, 50- or 100-L scale, scaleup rules are in effect to predict the following parameters:

- Drying time
- Solvent load, energy demand
- Residues after discharge
- Particle size changes due to shear on the product
- Wear of the agitator parts due to exposure to the product

Scaleup works best when the trials have been carried out under physical parameters (including pressure and temperature) that are identical to the full-scale process. If this is not possible, correction factors have to be applied to the scaleup formula. From a small-scale test, engineers can predict the formation of residues in the full-scale vessel can be predicted.

Tools to improve yields

When they are supposed to leave the vessel, solids often do not behave in ways that make it easy for process operators to fully empty the chamber, as the examples show (Figure 2). However, certain tools and strategies are available to help improve the discharge effect from vertical vessels and increase the yield.

Vessel geometry. The vessel geometry is generally designed and manufactured at the vendors' discretion. With respect to the mixing behavior, a filling-height-to-diameter ratio of 0.8 to 1.0 works best. For maximizing yields, minimizing the wetted surfaces is an important strategy. Table 1 shows sample data for drying vessels of three different geometries.

A flat-bottom vessel represents the design with the least wetted surface for a specific volume. Due to the almost perfect shape with respect to mixing,

FIGURE 4. The photos show helix-type impeller (left) versus a retrieved-anchor type (above)

the mixing of the solids is based on dynamic operation with a minimum blade surface. Vessels with a filling-height-to-diameter ratios above 1.8 (for example, a helix-type agitator) naturally have more wetted surface inside the vessel, but its slim cone bottom design improves outflow. Finally, typical "spherical shape dryers" combine both the short shape and the cone bottom design for best results in yield.

Using the vessel as a contact dryer, it is mandatory to reduce cold spots during the drying process. Unheated surfaces will result in condensate formation during the drying step. Agitator shafts are made of solid bar. In low-temperature drying processes, this shaft will stay cooler relative to the vessel and product temperature, leading to condensation. Condensate on these surfaces will attract dust to form a cake. This will happen in the non-agitated section of the vessel (for example, the shaft, top dome, nozzles and filter bay). In order to improve the yield, maximum surface and shaft heating is advised.

Impeller clearances. Solids dryers require an impeller system that both moves the bulk and "wipes" the walls. Since scraper designs have an extremely limited lifetime in solids applications, they cannot be applied, so tiny impeller-to-wall clearances are needed. The impeller must be designed with a small wall clearance to prevent the buildup of layers on the wall, and to improve heat transfer (if required) and yield. Table 2 shows typical impeller-to-wall clearances for various types of solid products.

Wetted surfaces quality. Even free-flowing solids, such as crystalline sugar, change to "sticky" when wetted. Therefore, the surface roughness selection should not be based on the final appearance of the solids, but should consider the overall process. For milling and processing tasks of coarse products (such as coffee beans, cocoa nibs, almonds, nuts, pistachios), where residues are accepted, the mill-finish wetted surfaces are qualified. How much material creates a cross-contamination hazard? For example, does only one bean or nut left create a cross-contamination hazard? In food-grade and pharmaceutical applications, polish is advised to reduce leftovers.

Agitator impeller design. Designing for maximum yield is a balance between wide blades for effective (low-shear) mixing and product buildup on the wide blade surfaces. Even solid granules with excellent flow properties will accumulate on a horizontal blade even when the shaft is spinning. A pitch angle of about 45 deg (retrieved anchor) or tilted blades (helix) are designed to reduce solid-layer buildup on the blade top (Figure 4). Always pay attention to the lower side of the blades. Static electricity or sticky products "hide" on the lower side and "ignore" the presence of gravity. Special spacer designs are available to fill in "dead zones" where solids may accumulate.

Agitator speeds and direction of rotation. Agitation in a solids bed is a low-speed, low-shear business. Shaft speeds are designed to gently move the bulk solids without excessive wear and particle size reduction. At the time of discharge, the bridge-breaking effect of the impeller is mandatory. The main pumping action of the solids impellers is "up". This upward motion is counterproductive when the vessel is close to empty. At this point — under consideration of torque limitations — reversing the direction of the impeller is mandatory to have a full discharge of the solids.

Speeding up the agitators to elevated speeds (higher rpm) will improve product discharge. Influenced by the centrifugal forces, solid layers on the blades are thrown outward. The more coarse the product, the more effective the elevated speed will be. Drive-speed restrictions, however, do limit this measure. For scaleup from smaller to higher volumes, the shaft´s rotational speed should be constant (not the tip speed).

Process. Time is money for batch drying processes, and fast mixing or drying is the goal. If the fast process results in excessive crust formation and contamination of difficult-to-reach areas, a process change in

TABLE 3. SMALL- VERSUS LARGE-SCALE BATCH DRYING		
	Small scale	**Full scale**
Product layer thickness	Residue = wetted surface × layer thickness	Residue = wetted surface × layer thickness
Speed for spin off	Best speed in rpm	Scale up by speed (not tip speed)
Bottom cone layer	Impeller wall clearance	Impeller wall clearance
Reverse operation	Check for excessive compaction	Check for excessive compaction

favor of slower drying, but less contamination (less yield), is advised.

A clever vacuum or lower temperature regime can help to reduce flash evaporation and dust formation. Filter port sizes should be designed for low gas-flow speeds.

Even with a perfectly designed vessel and process, 100% discharge of the dried solids might be out of reach. In this case, a wet cleaning/rinsing process has to be added. The liquid rinsing system will have the capability of removing solids from a vessel without residues.

Jet pulse injection. Removing solids layers via jet pulse lances has shown effectiveness in very small-scale vessels (25 to 50 L). Larger vessel trials did show that a typical 3 bars pressure lance will have a limited effect. High-pressure gas jets, however, increase dust explosion hazards due to their dense local energy input.

Testing and scaleup. There is good news about efforts to maximize yield and process scaleup. Generally, observations made at small scale will translate directly at large scale (Table 3). Effects seen at small scales (25- to 100-L test) can be directly applied to the full commercial scale. A product layer of 0.25 in. on the blade surface and on the vessel dome at small scale will be 0.25 in. at the full scale. Where such an example layer results in a yield of 80% in the small scale, it will convert to 95% at the full scale — considering the wetted-surface-to-filling ratio of the small scale compared to the full scale.

Concluding remarks

Products change when processed and show highly individual properties, so this article cannot elaborate on flow behaviors. This must be done in individual trials. Process equipment should offer flexibility to maximize yield. Small-scale testing is mandatory to predict discharge effects, and sometimes even reverse operation will force a paste out of the reactor without damage. Solid residues are often lost, and are sometimes a hazard. Process owners and equipment vendors should combine their product knowledge to improve yields in batch-drying process vessels. ■

Edited by Scott Jenkins

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Economic Indicators

2017 2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Dec. '19 Prelim.	Nov. '19 Final	Dec. '18 Final
CE Index	592.1	596.0	615.9
Equipment	716.9	723.3	751.2
Heat exchangers & tanks	610.9	619.9	667.3
Process machinery	714.5	720.7	731.2
Pipe, valves & fittings	951.1	955.9	979.9
Process instruments	419.0	419.2	420.2
Pumps & compressors	1075.8	1072.8	1037.3
Electrical equipment	561.9	561.6	553.7
Structural supports & misc.	750.2	764.6	827.2
Construction labor	338.3	336.0	339.5
Buildings	585.5	586.6	600.1
Engineering & supervision	312.7	313.3	316.3

Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

Annual Index:

2011 = 585.7

2012 = 584.6

2013 = 567.3

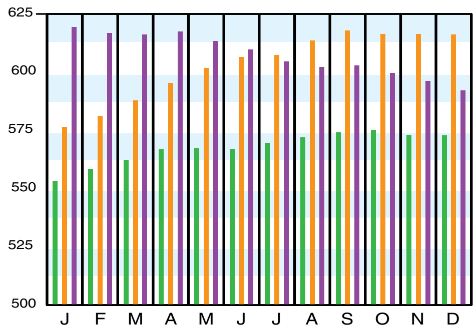
2014 = 576.1

2015 = 556.8

2016 = 541.7

2017 = 567.5

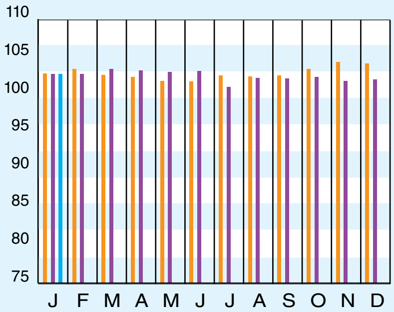
2018 = 603.1



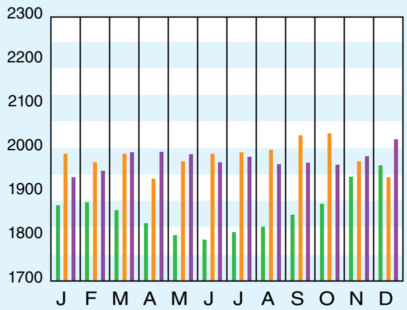
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO
CPI output index (2012 = 100)	Jan. '20	= 102.7	Dec. '19	= 102.2	Nov. '19	= 101.7	Jan. '19 = 104.2
CPI value of output, $ billions	Dec. '19	= 2,022.0	Nov. '19	= 1,987.5	Oct. '19	= 1,970.7	Dec. '18 = 1,951.9
CPI operating rate, %	Jan. '20	= 76.3	Dec. '19	= 76.0	Nov. '19	= 75.6	Jan. '19 = 78.2
Producer prices, industrial chemicals (1982 = 100)	Dec. '19	= 242.9	Nov. '19	= 245.7	Oct. '19	= 249.5	Dec. '18 = 262.4
Industrial Production in Manufacturing (2012 =100)*	Jan. '20	= 104.9	Dec. '19	= 105.0	Nov. '19	= 104.9	Jan. '19 = 105.8
Hourly earnings index, chemical & allied products (1992 = 100)	Jan. '20	= 188.4	Dec. '19	= 187.6	Nov. '19	= 187.1	Jan. '19 = 187.7
Productivity index, chemicals & allied products (1992 = 100)	Jan. '20	= 98.5	Dec. '19	= 97.9	Nov. '19	= 97.2	Jan. '19 = 97.3

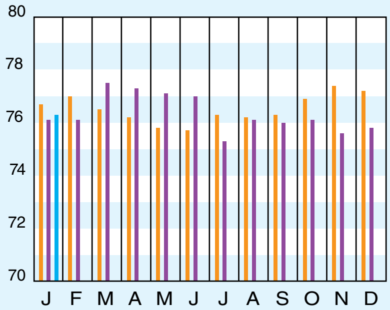
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for December 2019 (the most recent available) decreased from the previous month's value, the ninth decline in the last eleven months. Of the four major subindices comprising the overall CEPCI, the Equipment, Buildings, and Engineering & Supervision subindices decreased in December, while the Construction Labor subindex saw a small increase. The current CEPCI value is 3.9% lower than the corresponding value from a year ago at the same time. Meanwhile, the Current Business Indicators (CBI; middle) saw small increases in the CPI Output Index and the CPI Operating Rate for January 2020. The Productivity Index for Chemicals and Allied Products also rose slightly.